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of the

American Fisheries Society

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September 14, 15, and 16, 1949

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THE AMERICAN FISHERIES SOCIETY

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The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

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2.	William Clift	1872-1873	Albany, N. Y.
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4.	Robert B. Roosevelt	1874-1875	New York, N. Y.
5.	Robert B. Roosevelt	1875-1876	New York, N. Y.
6.	Robert B. Roosevelt	1876-1877[1]	New York, N. Y.
7.	Robert B. Roosevelt	1877-1878	New York, N. Y.
8.	Robert B. Roosevelt	1878-1879	New York, N. Y.
9.	Robert B. Roosevelt	1879-1880	New York, N. Y.
10.	Robert B. Roosevelt	1880-1881	New York, N. Y.
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20.	Eugene G. Blackford	1890-1891	Put-in-Bay, Ohio
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22.	Herschel Whitaker	1892-1893	New York, N. Y.
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24.	William L. May	1894-1895	Philadelphia, Pa.
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29.	John W. Titcomb	1899-1900	Niagara Falls, N. Y.
30.	F. B. Dickerson	1900-1901	Woods Hole, Mass.
31.	E. E. Bryant	1901-1902	Milwaukee, Wis.
32.	George M. Bowers	1902-1903	Put-in-Bay, Ohio
33.	Frank N. Clark	1903-1904	Woods Hole, Mass.
34.	Henry T. Root	1904-1905	Atlantic City, N. J.
35.	C. D. Joslyn	1905-1906	White Sulphur Springs, W. Va.

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[1] A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

36. E. A. Birge	1906-1907	Grand Rapids, Mich.
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45. Jacob Reighard	1915-1916	San Francisco, Calif.
46. George W. Field	1916-1917	New Orleans, La.
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48. M. L. Alexander	1918-1919	New York, N. Y.
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50. Nathan R. Buller	1920-1921	Ottawa, Canada
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58. C. F. Culler	1928-1929	Seattle, Wash.
59. David L. Belding	1929-1930	Minneapolis, Minn.
60. E. Lee LeCompte	1930-1931	Toronto, Canada
61. James A. Rodd	1931-1932	Hot Springs, Ark.
62. H. S. Davis	1932-1933	Baltimore, Md.
63. Fred A. Westerman	1933-1934	Columbus, Ohio
64. E. L. Wickliff	1934-1935	Montreal, Canada
65. Frank T. Bell	1935-1936	Tulsa, Okla.
66. A. G. Huntsman	1936-1937	Grand Rapids, Mich.
67. I. T. Quinn	1937-1938	Mexico City, Mexico
68. Fred J. Foster	1938-1939	Asheville, N. C.
69. T. H. Langlois	1939-1940	San Francisco, Calif.
70. James Brown	1940-1941	Toronto, Canada
71. John Van Oosten	1941-1942	St. Louis, Mo.
72. John Van Oosten	1942-1943	(No meeting)[2]
73. John Van Oosten	1943-1944	(No meeting)[3]
74. John Van Oosten	1944-1945	(No meeting)[3]
75. John Van Oosten	1945-1946	(No meeting)[3]
76. Joe Hogan	1946-1947	St. Paul, Minn.
77. H. H. MacKay	1947-1948	Denver, Colo.
78. Seth Gordon	1948-1949	Atlantic City, N. J.
79. Milton C. James	1949-1950	Winnipeg, Manitoba

---

[2] The annual meeting scheduled to be held in New Orleans, La., was cancelled because of the war emergency.

[3] No annual meeting scheduled because of the war.

In Memoriam

●

Thaddeus Surber, St. Paul, Minn.

Henry Beeman, New Preston, Conn.

●

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Part 1
Papers

A CONSIDERATION OF THE HOOVER REPORT[1]

IRA N. GABRIELSON
Wildlife Management Institute, Washington, D. C.

ABSTRACT

This paper presents the proposals of "task force" reports on agriculture and that on natural resources. It also outlines the recommendations presented in the majority report of the Hoover Commission which uses parts of both reports and that of the minority reports which closely followed the ideas of the natural resources group.

It endorses the idea of creating a Department of Natural Resources to handle public land and water resources, minerals, forests, and wildlife, as the most logical of the various presentations.

The Hoover Commission in its final report at the conclusion of a long study of Federal Government activities made the following recommendations affecting the administration and utilization of natural resources. It would retain the Department of the Interior built around an idea of a water-development and mineral-management service. It also would include a construction agency created largely by combining in Interior the present Bureau of Reclamation and the Army Corps of Engineers, together with the constructional functions now assigned to other agencies.

Briefly, the recommendations are as follows, it being understood that the present bureaus in the Department would remain there unless otherwise indicated.

1. The Department of the Interior should be given clear major responsibility for governmental development of the nation's water and mineral resources. Since these activities require large public works, other major public works also should be managed by the Department.
2. To these ends, the Interior Department should take over the flood-control and rivers-and-harbors work of the Army Engineers, plus Public Building Construction and Community Services from the Federal Works Agency. Also it should manage certain other major construction on assignment from other governmental agencies.
3. The following agencies should be shifted from Interior to other Departments: (a) Bureau of Indian Affairs to a new department; (b) Bureau of Land Management (except minerals) to the Department of Agriculture; (c) Division of Commercial Fisheries to the Department of Commerce.
4. A Board of Impartial Analysis for Engineering and Architectural Projects should be created in the President's office, consisting of five members of outstanding abilities appointed by the President. It would review and report on the economic, social, and technical worth of all projects proposed by the Interior Department. It also would review authorized projects periodically and advise as to their progress or discontinuance. Though the Hoover Commission tactfully refrains from mentioning it, such a board, with sufficient prestige, might materially diminish congressional logrolling and pork-barrel grabs.

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[1] Presented by C. R. Gutermuth.

This report, and its recommendations affecting conservation agencies, did not follow the reports of any of the three "task forces" which made recommendations affecting renewable natural resources. The report by one committee would have scattered the conservation agencies pretty largely through the government and would have put the Fish and Wildlife Service in a Public Works Department. The Agricultural Committee recommended a drastic reorganization of the Department of Agriculture and included a transfer to Agriculture of all major activities and functions of public-land administration. The "task force" on natural resources developed an even bolder and more far-reaching program. It proposed to abolish the Interior Department and create in its place a Department of Natural Resources, consisting of a consolidated water-development service to administer the present functions of the Bureau of Reclamation, the river-development functions of the Corps of Engineers, the power-marketing functions of Bonneville, the Southwest Power Administration and the Division of Power in Interior, certain river-development functions now administered by the Federal Power Commission, and specific functions of the Department of State relating to international boundary streams. To be more precise, the report on natural resources recommended:

> Retention of the Tennessee Valley Authority in its present form, but the establishment of additional valley authorities was opposed;
>
> Establishment of a consolidated Forest and Range Service, based on the present Forest Service and furthering its general policies, but including the forest and range management functions of the Bureau of Land Management and research functions of the Agriculture Department relating to forest insects and diseases;
>
> Regional decentralization of the Water Development Service and the Forest and Range Service, by river basins where practicable, to facilitate "grass-roots" decisions, interservice cooperation, and local participation in planning;
>
> Division of the Fish and Wildlife Service into two units, a Fishery Service and a Wildlife Service;
>
> Establishment in the Executive Office of the President of a Board of Coordination and Review to the end that only economically feasible projects shall be instituted by the resource agencies and especially by the Water Development Service;
>
> Re-establishment of the General Land Office as a record-keeping and title-holding agency for the public lands;
>
> The union into a Department of Natural Resources to consist of the Water Development Service, the Forest and Range Service, Geological Survey, Bureau of Mines, National Park Service, Fishery Service, Wildlife Service, and the General Land Office. The Department of the Interior would cease to exist (Collingwood, 1949).

The Hoover Commission, in its final report steered a course somewhat midway between the report by the Agricultural Committee and that on Natural Resources. It should be emphasized, however, that the report retained the feature of consolidating all water services in the Department of the Interior, but retained the Department of the Interior as presently constituted, except that the Bureau of Indian Affairs, the Bureau of Land Management, and the Division of Commercial Fisheries, now a unit of the present Fish and Wildlife Service, would be shifted out of the

Department. In making this latter recommendation, the Commission did not follow the report of any "task force." The one advocating the creation in the President's office of a board for the coordination of engineering projects has, on the other hand, been requested repeatedly by conservation agencies.

Needless to say, there are differences of opinion over which recommendations should receive the support of conservationists. Those organizations interested primarily in forests tend to support the recommendation of the transfer of the administration of public lands to Agriculture, which would leave Forestry in Agriculture where it has been for many years and where it has fought vigorously to stay. The Agricultural "task force" based its recommendation on the premise that trees and grass are crops. It argued that research, management, and conservation of all crops might well be concentrated in one organization. It recommended a drastic regrouping of present functions and assignments which would cause most of the present agencies in the Agriculture Department to disappear or be divided and distributed between regulatory services, conservation services, extension services, research services, and others.

That, in general, covers the various recommendations of the Commission and of the "task forces." Regardless of the name by which the Department is known, it seems to me that the recommendations of the "task force" on natural resources, with minor exceptions, proposes the soundest conservation program. Ignoring the perennial contest between Interior and Agriculture—the "task force" proposed to group the water-development services and public-land management agencies into a Water Development Service, Forest and Range Service, Geological Survey, Bureau of Mines, National Park Service, Fishery Service, Wildlife Service, and General Land Office in a Department of Natural Resources. This approaches closely the idea of a Department of Conservation or Natural Resources that has been advocated by many conservationists for several years.

Certainly this proposal would come closer to providing a coordinated administration of renewable resources than the others. Perhaps the one point that will be raised with conservationists most frequently will be to question the advisability of combining all water services into one huge unit and then placing fish and wildlife, national parks, and other relatively small but exceedingly important units in direct competition with this large division. Some will feel that it might intensify the disadvantage under which small bureaus now operate in Interior when their need for funds or their programs conflict with proposals of the Reclamation Service. All too often other interests must give way to the programs of that bureau. Perhaps if a coordination and review board were established in the office of the President simultaneously with a consolidation, there would be some check on the apparently endless ambitions of government-paid engineers to make over the entire face of America in the shortest time possible.

The one inconsistency that stands out in a review of the Commission's recommendations is the one which would divide the Fish and Wildlife Service into two units, a Fishery Service and a Wildlife Service. With this exception, the report recommends consolidation and closer coordination. In this instance only did the Commission recommend the division of one small unit into smaller units. In my judgment, it would be a serious mistake to follow this proposal. This would divide the present Fish and Wildlife Service, which is small now compared to many other government bureaus, into still smaller units which might make it even more difficult to deal successfully with large proposals than when presenting a united front. Furthermore, I can find no logic in this recommendation.

In many states, the same agency is handling the administration of these resources. The basic biological problems are largely the same—differing in details rather than fundamentals. The only argument advanced in favor of this recommendation is the understandable one of tradition. The Biological Survey and the Bureau of Fisheries were operated separately for many years and some of the present members of the Fish and Wildlife Service can remember this condition and perhaps hope to restore it.

Prior to the consolidation of the two services, I opposed the plan largely because I already had plenty of troubles in the administration of wildlife work. Some of my fears proved groundless, and from an administrative standpoint there were good reasons for the merger. The obvious advantage to both groups has been that of presenting a united front. Both lines of work have secured increased appropriations, additional money more adequately to perform their responsibilities—more than they ever were able to secure alone.

Consolidation gives those interested in outdoor recreation, both hunting and fishing, a single unit to deal with on their problems. There is an obvious advantage from this standpoint. I, therefore, believe that the recommendation calling for the division of the Fish and Wildlife Service into two units is a step backwards and one that should not be supported by the conservation organizations.

The proposal of the Commission to place the Division of Commercial Fisheries as a small unit in the Department of Commerce borders on the ridiculous. There can be no logical reason for it other than to provide some commercial-fishing interests with a group which might be more sympathetic to their pleas than an agency which must also listen to sport fishermen.

A few states have separate units for commercial and sport fisheries, the latter usually combined with the fish and game agency. In the majority of such cases, however, the two fishery units have spent fully as much time trying to undermine each other as they have in conducting their work. The same thing could be expected if the commercial-fishery groups succeeded in taking commercial-fishery activities and setting them off in a unit by themselves. In fact, the basic reasoning behind the desire for separation is one of the most potent arguments for keeping the administration of the resource in one agency.

It obviously would be foolish to divide administration and research work for one group of fish into separate parts, depending fundamentally upon whether the man who catches it is going to eat it himself or sell it for someone else to eat. The fishery resource is a unit and should be administered as a unit. Establishment of competing administrative groups would be a long step backward and an invitation to duplication of effort and wasted funds, which the Hoover Commission was attempting to correct. Certainly such an idea deserves no support from those who are really interested in the wise, efficient, and economical management of the resource so far as the Federal Government affects that management.

If the eventual reorganization follows the recommendation of the Hoover Commission Report, which is to a large extent that of the Agricultural "task force," those interested in fish and wildlife will be confronted with a rather difficult dilemma. Fish and Wildlife are affected by both land and water management. If the Commission Report is followed, water-development will be in one agency and land-management in another. The fish and wildlife unit, wherever placed, will be faced with the necessity of working across departmental lines to secure proper management.

The Natural Resources "task force" recommended a Department of Natural Resources which could administer both the public lands and the water resources. It is the only plan which would consolidate the administration of both resources, and that would give the fish-and-wildlife and national-park groups an opportunity to work within their own department with both land and water. These agencies still would have to cross departmental lines to work with those dealing directly with farmers and private landowners on crop and pasture land.

In conclusion, it seems that the proposal for the establishment of a Department of Natural Resources comes nearest to meeting the requirements of the conservation organizations and societies. This would do more to advance our programs than the proposals presented by any of the other "task forces" or by the majority report of the Hoover Commission, and it is my earnest recommendation that it be supported, with the one exception mentioned previously.

LITERATURE CITED

COLLINGWOOD, G. H.
1949. Conservation and the Hoover Report. Amer. Forests, Vol. 55, No. 4, pp. 12-13, 45-46.

THE LAKES AND LAKE FISHERIES OF MANITOBA

George E. Butler
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Abstract

Manitoba has a large fishery production harvested both by commercial fishermen and by anglers. This fishery, yielding annually on an average over 32,000,000 pounds of all species of fish, is made possible by the 26,789 square miles of lakes and streams which are within the province.

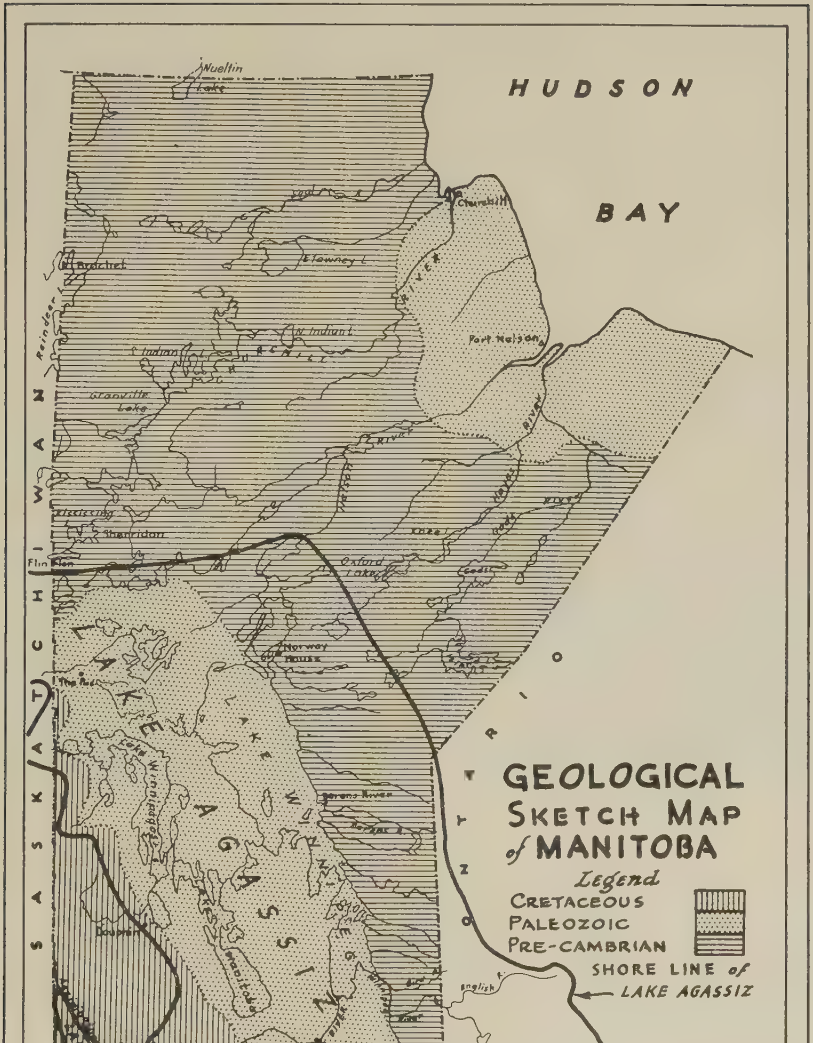
Many factors in the past have resulted in the different types of Manitoba lakes. Lake fisheries have been influenced to some extent by these factors. In recent years the development of commercial fishing, the efficiency of which increases year by year, has been of principal significance in the fisheries. Therefore, laws to regulate fishing in a manner to permit maximum sustained annual catch, and policies to improve existing fisheries where possible, have been the object of fishery management in Manitoba.

Introduction

Glacial activity has given Manitoba a large number of lakes and streams, the combined area of which is 26,789 square miles or 12.1 percent of the total provincial land and water area.

A description of representative lakes of the province would be incomplete without some mention of the two great glacial lakes which at one time covered much of Manitoba, large areas of Saskatchewan, Ontario, North Dakota, Minnesota and extended across the northern boundary of South Dakota (Figure 1). Lake Agassiz, the larger body, was a vast inland sea of fresh water originating from the melting of the continental glacier. It covered an area extending from the Nelson River in Manitoba to La Traverse in the northern part of South Dakota. On the west, from the western escarpment, now known in Manitoba as Pasquia Hills, the Porcupine, Duck, Riding and Pembina Mountains, Lake Agassiz extended easterly to near Island Lake. From thence its shoreline was in a southerly and easterly direction to east of Rainy Lake in Ontario and again southerly and westerly to include parts of Minnesota, North Dakota and South Dakota. It thus extended nearly 700 miles from north to south and a similar distance from east to west, and had a surface area of 110,000 square miles and a depth, at its greatest, of 600 feet or more.

Originally Lake Agassiz drained southward to the Missouri and Mississippi Rivers, through the channel which has been named River Warren. Later, as the ice block to the north receded, a drainage northward to Hudson Bay developed through the Nelson River. Lake Agassiz was gradually reduced in size, first by lowering of its southern outlet and later as the glacier to the north disappeared, by successively lower


Nueltin Lake
HUDSON
BAY
Seal R.
Churchill
Brochet
Reindeer L.
Etawney L.
N. Indian L.
S. Indian L.
CHURCHILL R.
Granville Lake
Port Nelson
RIVER
Nelson River
Hayes River
Kississing
Sheridon
Flin Flon
Knee L.
Oxford Lake
Gods L.
Gods River
Norway House
The Pas
SASKATCHEWAN
ONTARIO
LAKE AGASSIZ
Lake Winnipegosis
LAKE WINNIPEG
Berens River
Lake Manitoba
Dauphin
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WINNIPEG
St Boniface
Red River
English R.
Lake of the Woods
INTERNATIONAL BOUNDARY
GEOLOGICAL
SKETCH MAP
of MANITOBA
Legend
CRETACEOUS
PALEOZOIC
PRE-CAMBRIAN
SHORE LINE of LAKE AGASSIZ

FIGURE 1.—Geological map of Manitoba showing basic formations and outlines of postglacial lakes.

outlets in the direction of Hudson Bay (Upham, 1889). All that remains today of Lake Agassiz in Manitoba are Lakes Winnipeg, Winnipegosis, Manitoba, Dauphin, Cedar, Moose, Playgreen, St. Martin and Waterhen and a host of smaller lakes, mostly to the north and east of Lake Winnipeg.

Lake Souris situated to the west and north of Turtle Mountain and extending into North Dakota was the second large glacial lake in Manitoba. It also at first drained southward, but later outflowed through the Souris to the Pembina River (Upham, 1889). The Pelican, Rock, and Swan Lake chain is the present-day remnant of this channel, while Oak Lake and Whitewater Lake occupy terrain which was part of the Lake Souris basin.

In addition to the influence of Lake Agassiz, the geological formations of the province have had considerable bearing upon the character of the modern lakes. For the present purposes, the lakes of Manitoba will be grouped according to whether they are situated in the Mesozoic, the Palaeozoic or the Pre-Cambrian region (Figure 1). The Mesozoic shale covers the southwestern part of the province; the Palaeozoic limestone forms a wide band in the central region, extending northward in a northwesterly direction, together with the region in the northeastern part of the province between the Churchill, Nelson, and Hayes Rivers; the Pre-Cambrian, mostly granite, extends fan-like in a northwesterly direction from the extreme southeastern region of Manitoba to beyond the northern boundary of the province.

Lakes of Southwestern Manitoba (Mesozoic Area)

In the Mesozoic formation the lakes are shallow and produce only limited quantities of the larger fishes, but their scarcity, especially in the prairie region, makes them valuable as recreational centers. Foremost in this respect are Rock Lake, Killarney Lake, and lakes in the Turtle Mountain area. Rock Lake has yielded to anglers excellent catches of pike (*Esox lucius*) and yellow pikeperch or walleyes (*Stizostedion v. vitreum*). Killarney has been in the main a brown bullhead (*Ameiurus nebulosus*) lake. Both are shallow — not much over 16 feet deep — and both suffer from periodic winterkilling of fish. Oak Lake also has been a valuable angling lake and was noted for its pike. However, dry years and low water levels caused heavy winterkilling. Swan and Whitewater lakes are too shallow to contain the larger fishes, but together with Oak Lake they are important as waterfowl habitat.

The shallow waters of southwestern Manitoba are often highly productive of primary fish food, and large numbers of minnows frequently are present. The predominating species are usually the fathead minnow (*Pimephales promelas*) and the brook stickleback (*Eucalia inconstans*).

In the Turtle Mountain area the many shallow lakes beautify the winding roads and before the drought years, 1930-1934, Lake Max and Lake William provided anglers with good catches of yellow pikeperch. Lake Metigoshe, which is partly on the Canadian side of the border, produces an abundance of yellow perch (*Perca flavescens*) for its anglers, together with largemouth black bass (*Micropterus salmoides*) and walleyes.

In the Riding, Porcupine, and particularly in the Duck Mountain region, at altitudes approaching 2,000 feet above sea level, there are deep productive lakes, ranging from 90 feet to nearly 200 feet in depth. Together with these deep lakes, and often nearby, are shallower lakes which are ideally suited for warm-water fishes, and which produce pike and white suckers (*Catostomus commersonnii*) in abundance. A peculiar feature of the deep lakes in the three mountain areas is that although water temperatures and food are suitable for lake trout (*Cristivomer namaycush*), no trout exist naturally in these waters. In the past 9 years introductions of lake trout, brown trout *(Salmo trutta)*, and rainbow trout (*Salmo gairdnerii*) have been made in Clear, Childs, Laurie, Glad, East Blue, and West Blue lakes. In two of these, Clear Lake in the Riding Mountain and East Blue Lake in the Duck Mountain, lake trout have survived. Rawson (1948) gives an excellent picture of physical and biological conditions in Clear Lake.

FIGURE 2.—Typical Lake Winnipeg commercial fishing station at Black Bear Island harbour.

In the Porcupine Mountain the lakes are not well known, but in Whitefish Lake, a biological survey indicated that it was an extremely productive lake with whitefish (*Coregonus clupeaformis*) and tullibee (*Leucichthys sp.*) the predominating species. The depth of the lake is from 30 to 59 feet and June temperatures range from 60° F. at the surface to 54° F. at the bottom.

LAKES OF CENTRAL MANITOBA (PALAEOZOIC AREA)

The lakes in the Palaeozoic formation are those from which the bulk of the Manitoba commercial production of fish is obtained. Foremost in importance is Lake Winnipeg with an area of 9,398 square miles. Its eastern shore is in the Pre-Cambrian formation and its western shore and the greater part of its area lie in the Palaeozoic area. With the exception of one small region in the vicinity of Black Island, Lake Winnipeg is moderately shallow with depths in the northern portion averaging 60 to 72 feet and in the southern section, 30 to 36 feet. It has been fished commercially for 67 years and at present yields an annual crop of 17 to 20 million pounds of fish or approximately 50 percent of the production of the province. The whitefish from the northern portion of Lake Winnipeg are of particularly good quality and are sold under the trade name of "Selkirk Whites." The southern area is a large producer of yellow pikeperch and saugers (*Stizostedion canadense*). Lake sturgeon (*Acipenser fulvescens*) are found in the eastern shore waters, but commercial fishing for this species has been discontinued because of declining production. Fresh-water drum (*Aplodinotus grunniens*) is present in moderate abundance in the southern areas where it supports a small commercial fishery, the only one of its kind in Manitoba. Goldeyes (*Amphiodon alosoides*) are caught in Lake Winnipeg and have become a famous delicacy when processed and smoked. Lake Winnipeg is also the waterway over which large quantities of freight for northern settlements are transported.

Lake Winnipegosis, the second largest lake in the province, has an area of 2,086 square miles. It is a somewhat shallower lake than Lake Winnipeg (average depth not more than 24 feet). It has been fished commercially for 52 years and produces 5 million pounds of fish annually. At present commercial fishing is permitted in winter under the ice and during the fall in open water for yellow pikeperch.

Lake Manitoba, the third largest lake in the province, has an area of 1,817 square miles. It is relatively shallow over much of its area with average depths in the large southerly portion of approximately 20 feet. Lake Manitoba has been fished commercially for over 50 years with an annual production of 5 million pounds but since the turn of the century only winter fishing has been permitted. This lake is a heavy producer of high quality yellow pikeperch, and is somewhat unique inasmuch as infestation of tullibee with *Triaenophorus* cysts is practically unknown. It also has a larger average annual production in pounds per acre (5.01) than has any other large lake in Manitoba. Possibly related to this productivity is the fact that the water of Lake Manitoba is richer in nitrogen than that of Lake Winnipegosis and Cedar Lake (Elkins, et al., 1948).

Lake Dauphin has an area of approximately 200 square miles and is a typical marl lake which is gradually filling. It is very shallow with depths of 10 feet or less over much of its area, and maximum depths of 16 to 18 feet. In spite of this shallowness, Lake Dauphin supports a winter fishery which has at times yielded very heavy catches (420,000 pounds in 1935-36) of yellow pikeperch.

In the northern portion of the Palaeozoic regions of Manitoba are several important, although comparatively small lakes, like Cedar Lake, with an area of 500 square miles. It receives the Saskatchewan River at its western end and is comparatively shallow with a recorded depth of 55 feet (Elkins et. al., 1948). Together with nearby lakes it constitutes an important northern fishery.

Table 1 shows the commercial catch from the three largest and two smaller lakes in Manitoba, for the past 10 years, together with annual averages and averages of the production per acre. Lake Manitoba with only winter season produces more fish per acre than do any of the other lakes considered.

Atikameg or Clearwater Lake is 120 square miles in area and has a maximum depth of 105 feet. It is noted for cold, clear water with a Secchi-disc transparency of 32 feet. Although the water is clear, it is extremely rich in minute Crustacea. This lake, which is closed to commercial fishing, is the source of whitefish and lake trout eggs for Manitoba fish hatcheries and is famous for the lake trout angling that supports the summer resort business.

TABLE 1.—*Commercial fishery production from five lakes in Manitoba—expressed in thousands of pounds.*

Year and Item	Lake (pounds marketed (all species) from Lake)					Total production for province
	Winnipeg	Winnipegosis	Manitoba	Dauphin	Cedar	
1938–39	18,554	6,419	7,283	191	7	34,079
1939–40	15,633	5,306	5,627	305	120	28,359
1940–41	21,895	5,430	9,386	305	75	38,886
1941–42	20,162	5,557	8,975	318	128	36,811
1942–43	17,690	7,539	5,774	200	108	33,679
1943–44	18,177	7,130	3,720	191	104	33,414
1944–45	13,753	6,063	4,078	423	135	27,393
1945–46	16,330	5,701	5,953	327	125	34,244
1946–47	14,309	4,637	4,112	446	116	28,697
1947–48	16,438	4,874	3,401	418	144	30,110
10-year average	17,292	5,866	5,831	312	106	32,567
Pounds per acre	2.9	4.4	5.0	2.4	3.0	

Lake Athapapuskow with an area of 104 square miles, and the three Cranberry Lakes with a combined area of 21 square miles are interesting because their southern shores are in the Palaeozoic area, while their northern shores are in the granite or Pre-Cambrian formations. All four lakes are ideal recreational locations with exquisite scenery and many rocky islands to make sheltered water for boating and angling in almost any weather. Good lake trout angling is to be had in Second Cranberry and Athapapuskow.

The part of Manitoba between the lower Churchill, Nelson, and Hayes Rivers and southeasterly to the Manitoba-Ontario boundary, also in the Palaeozoic zone, contains many small lakes. To the fishery investigator they are practically unknown, and are too remote to be economically fished commercially. The eastern brook trout (*Salvelinus fontinalis*) is found, sometimes large and in abundance, in streams of this region. In the rivers of the northern portion of this zone, Arctic grayling (*Thymallus signifer*) occur in some abundance. An investigation of the native speckled trout in the Nelson and Hayes Rivers, their tributaries and the coastal waters of Hudson Bay has been made by Central Fisheries Research Station biologists, and a cooperative tagging program of this species is in progress.

LAKES OF EASTERN AND NORTHERN MANITOBA (PRE-CAMBRIAN AREA)

Approximately three-fifths of Manitoba lies in the granite portion of the Pre-Cambrian belt. The region contains hundreds of lakes varying in area from less than 1 square mile to 1,200 square miles. The deepest lakes in Manitoba and those which are known to contain native lake trout occur in this region. The Manitoba portion of the Pre-Cambrian belt extends from the southeastern part of the province, from a point approximately 60 miles east of Winnipeg to the Manitoba-Ontario boundary and from thence to the northern border of the province at 60° north latitude.

More than 100 lakes are found in Whiteshell Provincial Park which is wholly within the Pre-Cambrian shield and about 90 miles east of Winnipeg. Since the lakes in the park are used extensively by tourists and there has been some biological investigation on a number of them, a few of the more important waters will be described in detail.

West Hawk Lake with an area of 5.52 square miles and a known depth of 240 feet is one of the deepest lakes in Manitoba. It has typical trout water and yields lake trout in good quantity to summer anglers. In 1924 an introduction of 75 smallmouth black bass *(Micropterus dolomieu)* was made and the species became firmly established. These advantages coupled with the fact that the Trans-Canada Highway skirts the southern shore have led to the establishment of a large tourist business. At the northern extremity of the lake the Whiteshell Trout Hatchery is situated. Although the deeper parts of the lake appear to be somewhat barren, the crustacean, *Mysis relicta*, has been recorded. It is possible that this shrimp-like animal which inhabits deep water provides food for the tullibee and whitefish that retreat to the cool waters of lower levels during warm summer weather.

Lake George, Mantario Lake, and Forbes Lake with areas of 2 to 8.22 square miles, depths from 80 to 100 feet, and pH readings from 7.0 to 8.2, all contain lake trout. Horseshoe Lake (area approximately 3½ square miles and known depth 45.5 feet) does not contain trout but is a potential rainbow or brown trout lake. Echo Lake (area 6 square miles, known depth 70 feet, pH 7.6 to 8.0) is a beautiful warm-water lake.

Falcon Lake (area 6 square miles, depth approximately 80 feet, pH 8.3) is a comparatively warm-water lake, a great producer of primary fish foods, and an important recreational area. Rainbow trout have been introduced and good catches of yellow pikeperch or walleyes are made by anglers. In addition to natural advantages, Falcon Lake is easily accessible from good roads.

Crowduck Lake with its area of 22.38 square miles and maximum depth of 81 feet is one of the most beautiful lakes in Manitoba. It offers possibilities for the successful introduction of rainbow trout. During the past 6 years over 300,000 rainbow trout fingerlings have been planted in the lake with apparently no result. In 1947, 335 and in 1948, 331 adult lake trout were introduced. From these plantings of adults it is hoped that the species will be established.

In addition to the deep lakes in the Whiteshell region, there are many shallower lakes which produce an abundance of yellow pikeperch. Some of these lakes appear to be suitable for the introduction of smallmouth black bass, a species which is already well established in West Hawk Lake and Caddy Lake. Among the shallower lakes in this class are Meditation Lake, Granite Lake, Cabin Lake, Malloy Lake, Bedford

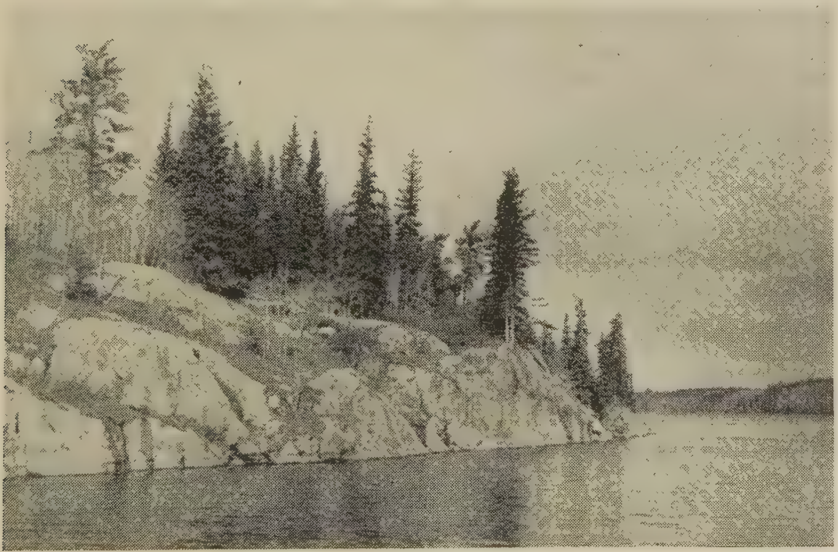

FIGURE 3.—A characteristic northern Manitoba scene, Manistikwan Lake, in Township 66 near Flin Flon, with Pre-Cambrian granite shore line, clad with coniferous and deciduous trees to the water edge.

Lake, Brereton Lake, Red Rock Lake, White Lake (3 square miles) and Big Whiteshell Lake (7 square miles).

That portion of the province north of the Whiteshell Forest Reserve and between the east shore of Lake Winnipeg and the Manitoba-Ontario boundary contains many lakes, some of which are extremely beautiful and ideally suited for tourist and recreational business. Aikens and Sasaginnigak Lakes are two worthy of mention.

Aikens Lake with an area of approximately 10 square miles and a depth of 249 feet, has a good population of lake trout, yellow pikeperch, northern pike, tullibee, and whitefish. In 1947, 7,000 eastern brook trout fingerlings were introduced. During an investigation in 1946 the writer caught tullibee in 100 feet of water with their stomachs full of *Mysis relicta.*

Sasaginnigak Lake with an area of approximately 22 square miles is a shallow lake producing yellow pikeperch, northern pike, whitefish, and an abundance of the smaller species, including minnows, darters, and log perch. It has numerous beautiful islands, and its sheltered waters will be ideal for boating and angling when it becomes accessible by road.

Gods Lake (area approximately 400 square miles) is a heavy commercial producer situated in the northeastern portion of the province where there are several large lakes. It yields over 600,000 pounds of whitefish and lake trout annually during the winter fishing season. In the Gods River, native eastern brook trout are found in great abundance. Island Lake (area approximately 375 square miles) supports a commercial fishery in winter which produces high class yellow pikeperch, but its large population of whitefish is heavily parasitized and cannot be used for market.

Utik Lake (area approximately 70 square miles) has many rocky islands clad with coniferous trees and high rocky shores. It is a deep lake with clear, dark-colored water and depths over 100 feet. Whitefish, yellow pikeperch, burbot and lake trout were taken in an overnight setting of gillnets during the course of an examination of the lake by the writer in 1943. Southern Indian Lake (area 1,200 square miles) is the largest lake in the Manitoba portion of the Pre-Cambrian shield. It is a heavy producer of high-quality whitefish and lake trout, and yields between 600,000 and 900,000 pounds of fish annually. No biological examinations of this lake have been made. Bigsand Lake (area approximately 100 square miles) located northwest of Southern Indian, is an extremely rich lake carrying a large population of lake trout and whitefish. Some commercial fishing has been done, but its isolated location has kept these operations in the experimental stage.

A number of the northern lakes in the Hudson Bay region are known to have arctic charr *(Salvelinus alpinus)* in a land-locked form. The estuaries of the Churchill and other northern rivers also at times have runs of this species as do lakes connected to Hudson Bay by streams which permit the ascent of spawning fish.

In the extreme northern portion of the province there are at least seven large lakes which are comparatively unknown. Among them are Tadoule (120 square miles); Nejanilini (115 square miles); Baralzon (104 square miles); Egenolf (50 square miles); Kasmere (100 square miles); and Putahow (36 square miles in Manitoba).

The southern part of Nueltin Lake which lies in Manitoba (230 square miles) is comparatively unknown. In 1947, however, Fowler and Harper (1948) reported 11 species of fish and the complete absence of Cyprinidae in the vicinity of Windy River which is at the northwestern extremity of the lake and in the Northwest Territories. Kennedy in 1948 (unpublished data) reports that Nueltin Lake is 100 miles long with an average width of 10 miles and an area 1,140 square miles. Depths of 100 and 150 feet are known and the water is clear with summer temperatures not exceeding 40° F. Break-up occurs between June 15 and July 15, and freeze-up between October 15 and November 1. Ice becomes 4 to 6 feet thick in southern and 6 to 8 feet thick in northern parts of the lake.

PROBLEMS OF FISHERY MANAGEMENT IN MANITOBA

The problems of lakes which have been fished commercially for many years usually arise from overfishing. Dymond (1948) aptly defines overfishing as that condition in which more fishing effort results in smaller catch. In Manitoba such a condition may be the result of too much fishing effort and use of gill nets with too-small mesh. Before these questions can be answered, a careful study of the status of fish populations in Manitoba lakes is necessary. This work is already in progress on Lake Winnipeg, where Dr. W. A. Kennedy of the Central Fisheries Research Station hopes to compare fish populations on Lake Winnipeg, which has been fished commercially over 67 years, with those of Great Slave Lake which is almost a virgin lake. On the administrative side, production limits have been set by law on all lakes in northern Manitoba, and in five of the seasons on the larger lakes, poundage limits have been set. In three of these seasons, poundage limits for individual fishermen have been set.

On Lake Winnipeg parasitic infestation of whitefish by the fish tapeworm, *Triaenophorus crassus* has caused concern. To lessen such infestation, a reduction of the numbers of tullibee, a necessary host to the parasite, without destruction of small whitefish has been recommended.

In the more extensively settled portions of Manitoba lowering of lake levels by deforestation and cultivation has made many formerly good fish lakes too shallow to carry fish over winter. Siltation from wind erosion has aggravated the problem in some prairie lakes. There is no immediate remedy for this situation although in the future it may be corrected to some extent by water conservation projects which will collect the spring run-off and control the outflow.

Winterkilling of game fish in some Manitoba lakes occurs periodically. Waters such as Killarney Lake in southern Manitoba, have a fair depth of water in places, but partial winterkills sometimes occur. Measures to raise the water level in regions where land is cultivated to the water's edge are restricted by the damage which would be caused by flooding arable land. Where lakes in recreational areas have winterkills, adult yellow pikeperch, yellow perch, or pike are restocked. In this manner the game fishes are reestablished in as short a time as possible.

Pollution of waters inhabited by fish is not yet a major problem in Manitoba and is limited to smelter plant and the pulp mill wastes. Where water conservation entails the building of high dams to collect and retain the spring run-offs, the fish culturist has an excellent opportunity. One such instance is Minnewashta Lake near Morden where a high dam created a lake approximately 1¼ miles long with a depth of 30 to 40 feet. This lake was first stocked with minnows and later with largemouth bass. Sticklebacks and crayfish found their way in naturally through an inflowing creek. It now has a productive largemouth bass fishery during the open season in July.

CONCLUSIONS

In conclusion it may be said that the lakes and lake fisheries of Manitoba are a valuable resource which provides employment for 6,000 to 7,000 commercial fishermen and creates a national income from exports of the commercial catch and from the tourist trade.

The problems connected with the administration of these fisheries are varied and extend geographically from sub-Arctic regions in northern Manitoba to semi-tropical mid-summer conditions in southern Manitoba. Extensive fishery research will be necessary to secure adequate facts upon which to base future management.

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GROWTH RATE STUDIES OF SAUGERS, *STIZOSTEDION CANADENSE CANADENSE* (SMITH) AND YELLOW PERCH, *PERCA FLAVESCENS* (MITCHILL) FROM LAKE OF THE WOODS, MINNESOTA

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Abstract

The scale method of growth analysis is applicable to the Lake of the Woods saugers and the body-scale relationship was described by a third degree polynominal. Saugers up to Age Class X were studied and the most rapid growth in length occurred during the first year of life. Lee's phenomenon was pronounced and was apparently due to the selective removal of the faster growing fish. Weight increased approximately as the 3.058 power of the standard length and the average "K" was 1.27. Females were more abundant than males. The number of eggs per female varied from 43,400-48,500. There appeared to be a correlation between the abundance of saugers in various year classes and the June rainfall and cooler summer temperatures during the year of hatching.

The yellow perch body-scale relationship was also curvilinear and was corrected for in the calculation of growth. Female perch grew more rapidly than the males and were longer-lived. Lee's phenomenon appeared to be due largely to selective sampling. No growth compensation was shown. The weight increased approximately as the 3.244 power of the standard length and the average "K" was 2.12. Females were more abundant than males in all except the 0-age class.

For the period 1932-41, 72 percent of the commercial catch of saugers and perch was taken in gill nets. The destruction of undersized saugers in these nets was about equal to the number of salable fish taken. Recruitment to the commercial fishery by both perch and saugers starts in the fourth year of life and continues into the sixth year for perch and the seventh for the sauger.

Introduction

A fishery investigation at Lake of the Woods was started in 1939 by the Minnesota Department of Conservation and the University of Minnesota. Lake of the Woods, on the boundary between Minnesota and Canada, supports an intensive commercial fishery in addition to a growing sport fishery. Life history studies of the yellow pikeperch, *Stizostedion vitreum vitreum* (Mitchill), and of the tullibee, *Leucichthys artedi tullibee* (Richardson), have already been published (Carlander, 1945a, 1945b). The present study deals with two species which are of considerable importance in the commercial fisheries, the sauger,

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Stizostedion canadense canadense (Smith) and the yellow perch, *Perca flavescens* (Mitchill). It has been suggested that these two species are increasing at the expense of the pikeperch (Carlander, 1945a, 1949).

The fish were collected from experimental gill nets with mesh sizes ranging from 1½ to 4 inches, stretch measure, and from commercial pounds nets, fyke nets, and gill nets (4-inch mesh). Scales and other data were collected each summer from 1939 through 1943. The scales collected since 1941 have not yet been examined, but since there is little likelihood of their being studied in the near future, it was deemed desirable to report on the growth data which have been calculated for the specimens collected from 1939 to 1941 and for smaller collections made at the fishery stations in October 1936 and 1937.

SAUGER

Saugers are most often taken with gill nets, but the 4-inch mesh nets used commercially are too large to catch them in numbers comparable to their abundance. Gill nets with mesh sizes up to 3.5 inches, stretch measure, are much more effective. Saugers were most commonly taken in waters more than 18 feet deep and seemed to remain fairly close to the bottom. They were only occasionally taken in nets floated near the surface. Lake of the Woods is not thermally stratified and therefore the distribution of saugers is not governed by temperature as is reported in Tennessee reservoirs (Dendy, 1945). Saugers were much more abundant in the open expanses than in the bays or among the islands.

BODY-SCALE RELATIONSHIP AND CALCULATION OF GROWTH

The relationship between the scale radius and body length of the saugers was determined from measurements of 2,827 scales from fish 50 to 375 millimeters long. The relationship can be described by a second degree parabola with the following formula:

$$L = 24.3 \text{ millimeters} + 2.97R - 0.0184R^2 + 0.000087R^3$$

where L = standard length in millimeters and R = anterior scale radius in millimeters (×16.4).

The length of the fish at the time each annulus was formed was calculated using "normal" scale measurements in the way described by Hile (1941), and using a nomograph with intervals modified to represent the corrected body-scale relationship (Carlander and Smith, 1944).

The validity of the annulus as a year mark was tested by methods similar to those used by Van Oosten (1929) and Hile (1941), and the annulus was found to be a satisfactory mark for the assessment of age. Scales collected at various times during the growing season indicated that annuli were formed in May or early June. Of 105 saugers taken in June 1941, 5.7 percent had not yet formed the annulus for the year.

All fish were measured while still fresh. Standard length was recorded for each fish and all measurements are given as standard lengths except where otherwise noted. The relationships between standard, fork, and total lengths were so nearly rectilinear that single conversion factors could be used on all sizes of saugers, as follows:

Fork length = 1.102 standard lengths, and
Total length = 1.159 standard lengths.

These coefficients were based upon measurements of 1,888 and 645 Lake of the Woods saugers, respectively, ranging in standard length from 50 to 375 millimeters.

AGE AND GROWTH OF SAUGER

Saugers from age class O through X were collected, but the numbers in the younger age classes were relatively low. Growth rates of the individual saugers vary considerably (Table 1). For example, some of the 4-year-olds were over 50 percent longer and over 300 percent heavier than others of the same age. Some attained the legal fork length of 12 inches while they were 3-year-olds, but others were not legal length at 5 years.

TABLE 1.—*Lengths and weights of Lake of the Woods saugers in each age class at time of capture.*

Age class	Standard length in millimeters			Weight in grams		
	Number	Mean	Range	Number	Mean	Range
O	1	86				
I	5	144	130–152	1	57	
II	152	169	140–254	38	74	28–255
III	201	229	165–298	28	216	85–340
IV	449	274	210–330	103	305	113–454
V	518	300	260–356	346	369	227–595
VI	173	311	273–362	109	436	312–567
VII	47	330	305–375	32	531	369–794
VIII	9	340	311–368	8	574	454–709
IX	2	365	362–368	2	737	709–765
X	2	343	337–349			

The most rapid growth in length occurs during the first year of life and the annual increment decreases each successive year (Table 2). Growth data on males and females were combined because the commercial fish are shipped without being cut open and because the determination of the sex of saugers is difficult during the summer. Higgins (1936) reported that male and female saugers in Lake Erie grew at the same rate during the first 3 years, but that in later life females grew more rapidly than males. The Lake of the Woods saugers show a similar sexual difference in growth rate (Table 3), but the difference in growth was generally small. The growth rate in Lake of the Woods appears to be about average when compared to the published reports on saugers in other waters (Hart, 1928; Bajkov, 1930; Deason, 1933; Eschmeyer and Jones, 1941; Eddy and Carlander, 1942).

TABLE 2.—*Average calculated standard lengths in millimeters at each annulus of saugers, Lake of the Woods, 1939 to 1941—summarized by classes.*

Age class and item	Number of fish	Annulus									
		1	2	3	4	5	6	7	8	9	10
I	7	97									
II	121	102	153								
III	129	112	165	211							
IV	229	114	163	205	242						
V	234	106	160	202	240	276					
VI	111	111	159	197	235	265	295				
VII	40	106	154	190	223	255	287	318			
VIII	7	107	147	182	216	242	269	296	309		
IX	3	104	147	183	216	244	263	294	323	346	
X	2	99	138	168	202	228	251	273	295	312	330
Grand average	883	109	160	203	238	270	291	312	310	332	330
Average annual increment		109	51	42	37	33	30	30	19	21	18
Annual increment in grams		18	29	59	75	89	94	107	63	87	78

TABLE 3.—*Average calculated standard length in millimeters of male and female saugers—standard deviation is indicated in parentheses.*

Age class	Sex	Number Examined	Annulus						
			1	2	3	4	5	6	7
III	Males	11	120 (12)	174 (11)	222 (13)				
	Females	5	123 (12)	180 (12)	226 (11)				
IV	Males	21	115 (8)	164 (11)	208 (12)	248 (13)			
	Females	22	118 (13)	167 (17)	211 (12)	252 (15)			
V	Males	44	110 (6)	159 (7)	201 (7)	236 (9)	274 (9)		
	Females	83	110 (7)	160 (8)	203 (10)	243[1] (11)	283[1] (12)		
VI	Males	9	109 (4)	156 (7)	194 (10)	230 (9)	262 (13)	292 (19)	
	Females	12	108 (8)	159 (7)	200 (10)	236 (9)	270 (10)	302 (12)	
VII	Males	1	106	154	188	222	256	279	309
	Females	9	105 (7)	149 (10)	185 (7)	217 (10)	251 (10)	282 (4)	310 (11)

[1] The difference between the average lengths of males and females is statistically significant by "Student's t test", 95 percent confidence, only in the instances marked.

The calculated growth data for each year's collection showed Lee's phenomenon of apparent change of growth rate. Selective sampling, which is the most generally accepted explanation of the phenomenon (Van Oosten, 1929; Hile, 1936), probably is the principal cause in most of these collections. The 1941 data, however, were largely collected by experimental gill nets with mesh sizes ranging from 1.5 to 4 inches, stretch measure, which are not especially selective. Also in the 1941 data Lee's phenomenon was not apparent until after the fourth year class, which is the year that saugers first enter the commercial fisheries in numbers. It is therefore suggested that the phenomenon in this case is due to the progressive removal of the faster-growing fish and to the tendency for slow-growing individuals to live longer. This same explanation was given for Lee's phenomenon in certain samples of yellow pike-perch from Lake of the Woods (Carlander, 1945a). With the saugers, however, as will be pointed out later, the removal by the fishery is not as intensive nor as selective of larger individuals. No better explanation can be given at the present time, however.

Although the annual increment in length decreases as the fish grow older, the annual increment in weight increases through the seventh year (Table 2). In the seventh year, the average increase in weight was more than the increase during the first 3 years combined.

LENGTH-WEIGHT RELATIONSHIP OF SAUGERS

The mathematical relationship between the standard length in millimeters (L) and weight in grams (W) of the Lake of the Woods saugers can be described by the following formula:

$$\text{Log } W = -5.03387 + 3.058 \text{ Log } L$$

The weight increases approximately as the 3.06 power of the standard length. Higgins (1936) reported that the Lake Erie saugers increased in weight as the 3.14 power of the standard length. The average coefficient of condition, K, of 508 saugers collected in 1942-43 was 1.27. There was little indication of change in plumpness as the length increased. Additional length-weight data recorded to the nearest ounce rather than the nearest gram collected in 1939-41 also showed no correlation between K and length. There was some indication that the males had slightly higher K values than females of the same length.

SEX RATIO, AGE AT MATURITY, AND FECUNDITY

Of 1,561 saugers which were sexed, 1,035 or 66 percent were females. There did not seem to be any shift in the sex ratios from age class II to age class VIII. Very few data are available as to the age at which the Lake of the Woods saugers become mature. In June 1941, three saugers were taken with a few eggs remaining in the oviducts which indicated that the fish had spawned a short time previously. These three fish were all 4 years old. Deason (1933) reported that in Lake Erie, male saugers were usually mature at 9.5 inches while females did not begin to mature until they reached 10.5 inches. Three female saugers, 305 to 311 millimeters standard length, collected in December, 1941, had 43,000, 46,500, and 48,500 eggs, respectively, as determined by counting small samples and measuring volumes by the water displacement method.

YEAR CLASS ABUNDANCE OF SAUGERS

The ages of saugers caught in pound nets from 1939 to 1941 indicated a difference in the relative abundance of various year classes in the population (Table 4). The 5-year olds were unusually abundant in 1939, the 6-year olds in 1940, and the 7-year olds in 1941 which indicated that the 1934 year class was more abundant than other year classes. Samples collected at the fisheries in the fall of 1936 and 1937 show another dominant year class. In 1936, 80 percent of the saugers were 4-year olds, and in 1937, 65 percent were 5-year olds. On the basis of these data, the various year classes can be ranged from most to least abundant as follows: 1934, 1932, 1935, 1931, 1936, 1937, and 1933. The amounts of rainfall in inches in June of these years were respectively: 6.1, 3.1, 3.8, 1.5, 2.5, 1.3, and 1.6. The summations of temperatures above 60° F. in degree-months for the same years were respectively: 9.6, 19.7, 15.2, 19.2, 19.1, 23.0, and 23.4. These data suggest a positive correlation between the abundance of saugers and the rainfall during June of the year in which they hatched and a negative correlation with high temperatures during the first summer. No other correlations between the abundance of saugers and water levels, rainfall, or temperature during other months appeared significant.

TABLE 4.—*Age class composition of saugers from commercial pound nets, 1939 to 1941—expressed as percentage of total fish.*

Year	Number fish	Age class							
		III	IV	V	VI	VII	VIII	IX	X
1939	42		12	59	20	7	2		
1940	401	1	13	42	37	5	2		
1941	347	3	16	31	32	14	2	1	1

YELLOW PERCH

The yellow perch are also taken most readily in gill nets with mesh sizes up to 3.5 inches, stretch measure. Smaller perch were taken primarily in water less than 18 feet deep but the larger perch were quite evenly distributed in waters up to 35 feet deep, the maximum depth in the American portion of the lake. Perch remained close to the bottom and were seldom taken in gill nets suspended near the surface.

BODY-SCALE RELATIONSHIP AND CALCULATION OF GROWTH IN PERCH

The relationship between the scale radius and body length of the yellow perch from Lake of the Woods, as determined from measurements of 1,536 scales from fish 19 to 289 millimeters long was satisfactorily described by two second degree parabolas. The first parabola, which fitted the data on perch from 50 to 150 millimeters long, had the following formula:

$$L = -92.4 \text{ millimeters} + 4.55R - 0.0324R^2 + 0.000098R^3$$

The second parabola fitted the data at both ends of the distribution but not in the center and had the following formula:

$$L = 11.0 \text{ millimeters} + 2.022R - 0.01278R^2 + 0.0000454R^3$$

Growth rates for individual fish were calculated in the same manner as that used for saugers. Hile and Jobes (1941) found that although direct proportion computations could be used in the calculation of growth rates for Saginaw Bay perch over 102 millimeters long, the computations of lengths less than this had to be corrected for differences in the body-scale relationships.

The mathematical relationship between standard and fork lengths is fairly constant and can be represented by a single coefficient, but that between the standard and total length changes with increases in length so that several factors must be used for accurate conversion:

Fork length = 1.114 standard lengths
Total length = 1.160 standard lengths up to 150 millimeters
Total length = 1.154 standard lengths, 151 to 200 millimeters
Total length = 1.146 standard lengths, over 201 millimeters

These coefficients were based upon 1,774, 208, 35, and 27 Lake of the Woods perch, respectively.

TABLE 5.—*Lengths and weights of Lake of the Woods yellow perch in each age class at time of capture.*

Age class	Standard length in millimeters			Weight in grams		
	Number	Mean	Range	Number	Mean	Range
O	474	44	32–70			
I	51	112	70–127	1	28	
II	184	128	102–197	1	170	
III	164	196	108–266	36	171	85–284
IV	244	227	171–266	65	239	142–254
V	123	238	178–291	88	347	142–595
VI	60	250	191–318	44	411	198–680
VII	19	255	216–286	16	455	340–595
VIII	15	263	229–292	12	512	369–680
IX	2	266	273–279	2	553	510–595
XI	1	279		1	680	

AGE AND RATE OF GROWTH OF PERCH

Yellow perch from age class 0 to XI were examined and the sizes in each age class varied considerably (Table 5). The most rapid growth

TABLE 6.—*Average calculated standard length in millimeters at each annulus of perch from Lake of the Woods, 1939 to 1941—summarized by age classes.*

Age class and item	Number of fish	Annulus										
		1	2	3	4	5	6	7	8	9	10	11
I	44	88										
II	186	79	112									
III	67	87	128	161								
IV	87	88	128	163	188							
V	100	86	123	156	181	211						
VI	53	82	117	149	174	197	230					
VII	19	79	111	142	167	192	213	241				
VIII	15	74	104	131	153	175	194	221	249			
IX	2	74	106	131	154	172	185	210	229	260		
XI	1	65	91	108	129	148	166	178	193	213	238	264
Grand average	574	84	118	154	177	199	219	229	243	244	238	264
Average annual increment		84	34	33	25	27	27	27	26	27	25	26
Annual increment in grams		15	27	54	45	70	102	88	100	104	93	118

in length occurs during the first year of life and the annual increment during the second year is less than half that of the first year (Table 6). After the third year, the annual increment is about the same from year to year. Although it is not shown in the general growth curve, the growth of individual perch usually shows a rise in the fourth to the sixth year of life so that the annual increment during these years may be more than that during the second and third year.

TABLE 7.—*Calculated standard length in millimeters of male and female yellow perch.*

Age class	Sex	Number of fish	Annulus							
			1	2	3	4	5	6	7	8
I	F	24	89							
	M	19	87							
II	F	135	79	112						
	M	43	79	112						
III	F	24	86	124	157					
	M	17	83	120	149					
IV	F	38	92	132	166	193				
	M	14	88	125	159	184				
V	F	43	90	127	161	185	219			
	M	9	87	122	151	183	201			
VI	F	21	87	121	153	178	202	239		
	M	3	87	120	152	177	201	234		
VII	F	5	84	117	147	176	195	225	254	
	M	2	76	107	136	160	179	200	223	
VIII	F	3	78	107	136	160	186	204	239	273

Female perch apparently grew more rapidly than the males (Table 7), but the differences were usually not great. This difference in rate of growth was evident even during the first year of life. Out of 396 young perch collected on August 17, 1940, the females had a slight advantage in size as follows:

	Number	*Mean standard length*	*Standard deviation*
Males	224	42.37 mm.	6.78 mm.
Females	172	43.80 mm.	8.23 mm.

This gives a t value of 1.90 which is just at the 0.05 level of significance. Females apparently also live longer than the males since the majority of the older perch were females. Eschmeyer (1937, 1938) and Hile and Jobes (1942) also found female yellow perch to be longer lived.

The growth rate of the Lake of the Woods perch was more rapid than that reported for other waters, particularly after the third year (Eddy and Carlander, 1942; Schneberger, 1935; Hile and Jobes, 1941, 1942; Harkness, 1922; Eschmeyer, 1938, 1939; Beckman, 1949).

Lee's phenomenon was marked in the 1939 and 1940 samples but was not evident in the 1941 sample. The first two samples were taken from larger mesh gill nets and from the commercial fisheries, and therefore were selective of the larger fish. The 1941 sample, on the other hand, included a large number of smaller perch taken in small mesh gill nets so that the sampling selectivity was very slight. No growth compensation was shown by the Lake of the Woods perch. Individuals that made rapid growth during the first year of life usually maintained this advantage and continued to grow more rapidly than those which made a slow start.

Although the annual increment in length decreases as the perch grow older, the annual increase in weight increased through the sixth year (Table 6).

LENGTH-WEIGHT RELATIONSHIP OF PERCH

The mathematical relationship between standard length in millimeters (L) and weight in grams (W) of the Lake of the Woods perch (Table 11), can be described by the following formula:

$$\text{Log } W = -5.2236 + 3.244 \text{ Log } L$$

The weight increases approximately as the 3.244 power of the standard length. In Saginaw Bay the weight of yellow perch increased as the 3.1173 power of the standard length (Hile and Jobes, 1941); in Green Bay as the 3.133 power; and in Lake Michigan as the 2.811 power (Hile and Jobes, 1942).

The average coefficient of condition, "K," of 340 yellow perch collected in 1942-43, was 2.12 with a range of 1.97-2.35. Lake of the Woods perch are apparently plumper than perch from most other populations studied (Hile and Jobes, 1941, 1942; Eschmeyer, 1937; Schneberger, 1935; Beckman, 1948). The average "K" value tended to increase irregularly with increase in age and length of the fish, a tendency which was also noted in additional length-weight data collected from 1939-41, but recorded only to the nearest ounce. Hile and Jobes (1942) found that the average K increased with age in the perch population in Green Bay, but decreased among the perch in Lake Michigan. In Lake of the Woods, male perch tended to be heavier for their length than the females.

SEX RATIOS AND FECUNDITY OF PERCH

Female perch were much more abundant than the males in our Lake of the Woods collections, at least in the older age classes (Table 8)[2]. In some age classes there were five females for each male. The 0-age class showed a slight dominance of males. In Ottertail Lake, Minnesota[3] the sex ratio of perch was approximately 1 to 1 early in life but the females were predominant in older age classes. Eschmeyer (1937, 1938) found the same characteristics in perch-bound lakes of Michigan.

TABLE 8.—*Sex ratios of yellow perch at Lake of the Woods, 1939-1941*

Age class	Number males	Number females	Number of females per 100 males
O	224	172	77
I	19	29	153
II	48	135	314
III	17	24	141
IV	14	38	271
V	9	43	478
VI	3	21	700
VII	2	5	250
VIII	0	3	
Not aged	109	283	260
Totals and average	440	753	171

In Lake of the Woods, perch with ripe milt were taken as late as July 7th. One female perch, 222 millimeters long, collected in December, 1941, had 48,000 eggs.

SAUGERS AND YELLOW PERCH IN THE COMMERCIAL FISHERIES

For the period 1932-41, 72 percent of the commercial catch of both the saugers and perch was caught in gill nets, 21 and 13 percent in pound nets, and 7 and 15 percent in fyke nets, respectively. Many of the saugers taken in the commercial gill nets were undersized because the saugers catch by their teeth. For every 100 salable saugers taken in gill nets, another 108 were thrown away because they were under the legal fork length of 12 inches. Of these at least 80 were dead before they were released. Very few undersized perch were taken in any of the commer-

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[2] Dr. Raymond E. Johnson reports (personal communication) that in later studies on Lake of the Woods male or female perch were collected at will by setting nets in various areas.

[3] Minnesota Dept. Conservation, Bureau of Fisheries Research, Investigational Report No. 25, 6 pp. typewritten, 1941. K. D. Carlander.

Table 9.—*Age class composition of saugers and yellow perch in commercial catches, Lake of the Woods, 1939-1941, expressed as percentage of total catch.*

Species	Type of catch	Number measured	Age class I	II	III	IV	V	VI	VII	VIII	IX
Sauger	Fishery[1]	1504			2	11	53	25	7	1	1
	Commercial gill nets	2437	1	12	14	19	29	15	7	2	1
	Pound nets	790			2	14	49	24	9	1	1
Yellow perch	Fishery	1089			8	29	33	18	6	5	1
	Commercial gill nets	315			1	2	30	27	19	14	7
	Pound nets	551		1	11	32	32	17	5	2	

[1] Fish collected at shore fishery where type of gear used in catch could not be determined.

cial gear since the commercial gill nets select only the larger and older perch. Most of the saugers and yellow perch taken commercially were 5 or more years old (Table 9). The numbers of fish in older age classes decrease quite rapidly due to natural and fishing mortality. Recruitment to the commercial fishery starts in the fourth year of life and may continue into the sixth year for the yellow perch and the seventh year for the sauger (Table 10).

Table 10.—*Percentages of each class of saugers and yellow perch within the legal lengths of 12 and 8 inches respectively.*

Age class	Sauger	Yellow Perch Males	Yellow Perch Females
III	3	25	28
IV	16	86	95
V	91	100	98
VI	99	100	100

Saugers and yellow perch have usually not comprised a major part of the commercial yield in Lake of the Woods (Table 11). During the years 1936 and 1937, the catch was much greater than before or since. It is believed that this increase was due not to an increase in these species though there may have been some increase, but rather to an increased use of smaller meshed gill nets. The fishermen say that there was much illegal netting during that period and the large number of arrests made toward the end of the period, as the result of increased enforcement, further substantiates this belief.

The present regulations do not permit the capture of perch and saugers in relation to their abundance. Changes to permit greater utilization of these species might result in increased yellow pikeperch production by reducing the competition.

TABLE 11.—*Annual commercial yield (in thousands of pounds) of yellow perch and saugers in the Minnesota waters of Lake of the Woods, 1915-1945, and percentages of total catch which each species contributed.*[1]

Year	Yellow perch		Saugers	
	Catch	Percentage	Catch	Percentage
1915	6	0.4		
1916	6	0.5		
1917	1	0.5		
1918	6	0.4		
1919	7	0.5		
1920	7	0.5		
1921	6	0.6		
1922	6	0.6		
1923	8	0.7		
1924	13	1.0		
1925	15	1.0		
1926	17	0.9	55	3
1927	10	0.5	51	3
1928	12	0.9	38	3
1929	25	1.3	41	3
1930	55	2.5	74	3
1931	56	2.8	219	11
1932	37	1.5	216	9
1933	40	7.2	243	13
1934	44	2.2	283	14
1935	78	3.5	347	16
1936	156	7.3	391	18
1937	219	11.2	415	21
1938	54	3.0	88	5
1939	50	2.8	69	4
1940	41	1.9	82	4
1941	17	1.1	69	4
1942	12	0.8	60	4
1943	13	1.0	57	5
1944	9	0.7	33	3
1945	6	0.6	38	4

[1] Statistics from published reports of Minnesota Department of Conservation and from "Fisheries Industries of the United States".
Prior to 1926 separate statistics were not kept on saugers.

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THE AGE AND RATE OF GROWTH OF THE SHEEPSHEAD, *APLODINOTUS GRUNNIENS* RAFINESQUE, IN THE UPPER MISSISSIPPI RIVER NAVIGATION POOLS[1]

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Abstract

This study is one of a series of studies made of the fisheries of the upper Mississippi River as part of the program of the Upper Mississippi River Conservation Committee. The scale method was validated for the species and growth rates were calculated. Latitude was not a factor in the growth of 902 sheepshead taken from navigation pools 4A, 8, 10, and 17. Growth rates within different areas of the same pool and from pool to pool were sufficiently alike so that the growth from Lake Pepin to Muscatine, Iowa, can be considered uniform.

Sheepshead from the upper Mississippi River grow more rapidly than those of Lake Erie. Average growth for the first year was 4.9 inches followed by a 4.0 inch growth during the second year. At the end of the seventh year they had reached a total length of 18.1 inches, 2.3 inches longer than 7-year-old sheepshead from Lake Erie. Annual growth rates observed for the period 1939 through 1947 were 7.8 percent above the average in 1939 and 7.3 percent below average growth during 1945. No relationship existed between growth rates and average annual water levels. During the third year of growth 23 percent of the males reach maturity. The first mature females were observed during their fifth year. Growth rates of earliest maturing males and females were far above average.

Management implications of these investigations of the sheepshead are (1) the uniformity of the growth pattern requires uniform regulations in the area studied and (2) maintenance of spawning stock is dependent on adequate survival of 16-inch females, the length at which more than 50 percent of the females are mature.

Introduction

The fresh-water sheepshead, *Aplodinotus grunniens*, is an important species in the fisheries of the Mississippi River. It generally ranks third in abundance and value and is exceeded in production only by carp and buffalo. Management and evaluation of present exploitation of this fish, like that for other commercial species, depends upon knowledge of growth and age classification. Since little information is available on this phase of its life history in the area under observation, the present study was initiated. Difficulties encountered in the assessment of age indicated the necessity of validation of the scale method for application to sheepshead of these waters. Other problems explored related to effect of latitude on growth rate, seasonal fluctuations in growth, and the relationship of size at maturity to the average size of fish taken by the present fishery.

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[1] Paper No. 2567 of the Scientific Journal Series of the Minnesota Agricultural Experiment Station, St. Paul 1, Minn.

The physiographic characteristics of the upper Mississippi River in the area where this study was conducted were greatly changed from 1930 to 1938 when a series of locks and dams (18 impoundments in all) were completed between Minneapolis, Minnesota, and Muscatine, Iowa. The primary purposes of the projects were the control of water flow and the maintenance of a 9-foot channel to aid navigation. Conservation agencies of the bordering states recognized the need for a cooperative biological study of this altered environment to determine the extent of the fish and wildlife resources and to develop a uniform type of management for maximum production.

In December of 1943 representatives from the conservation departments of Illinois, Iowa, Minnesota, Missouri, and Wisconsin and the U. S. Fish and Wildlife Service formed the Upper Mississippi River Conservation Committee for the purpose of carrying on investigations of the fishery and wildlife resources from Caruthersville, Missouri, to Hastings, Minnesota (Smith, 1949). Two subcommittees were formed, one for fishery investigations, the Technical Fish Committee, and the other for game investigations. The Technical Fish Committee was developed as two units, the northern unit being concerned with biological investigations of the impoundments from Dubuque, Iowa, to Hastings, Minnesota, and the southern unit with studies from Caruthersville, Missouri, to Dubuque, Iowa. Work was started in the spring of 1944 and has continued to the present time. In 1948 the senior author participated in the field work of the upper unit and collected a large part of the material for the sheepshead study. Supplementary data collected in 1946 and 1947 by other workers were made available by the Upper Mississippi River Conservation Committee.

The total commercial catch of sheepshead in the upper Mississippi River for 1948 was 617,600 pounds valued at $74,112. Sheepshead represent 6.8 percent of the total commercial catch of 9 million pounds and 10.6 percent of the total value of $701,613 (Upper Mississippi River Conservation Committee, 1950). Wisconsin, Iowa, and Illinois produced the greater part of the upper Mississippi River catch. South of Caruthersville, Missouri, importance of this fish in the commercial catch is greater than in the upper river. At present the take of sheepshead is regulated only by restrictions on the type of gear used for the catch of all fish.

The geographic distribution of the sheepshead and the important factors influencing its original dispersal are described by Barney (1926). A sheepshead cranium found in post-glacial marl of northern Michigan provides evidence that its former distribution in Michigan was north of its present range in that state (Hubbs, 1940). The post-larval stage prior to the formation of scales was described by Fish (1932). Early life histories of other species of Sciaenidae have been studied by Pearson

(1930) and Hildebrand and Cable (1930). References to the sheepshead on the upper Mississippi River were made by Wagner (1908) and Coker (1929 and 1930). Van Oosten (1938) described the age and growth of Lake Erie sheepshead. An age and growth analysis was made on a sample of 168 sheepshead from five Minnesota lakes and rivers by Eddy and Carlander (1942).

MATERIALS AND METHODS

Calculations on growth were made from scales of 902 sheepshead collected in Pools 4A, 8, 10, and 17 of the upper Mississippi lock and dam system during the summer months of 1946, 1947, and 1948. These pools extend from Lake Pepin to Muscatine, Iowa. Impressions of the scales for study were prepared in cellulose acetate using a heated pneumatic press. Unpublished studies by the senior author on the impression method indicate that there is a very small difference between measurement along the anterior radius made on impressions and on the original scale in gelatin (average, 2.9 percent). Differences in this measurement are actually greater between the dry scale mount and the glycerin-gelatin mounted scale. Impressions of the general scales were studied using a micro-projector of 25.5x magnification. Calculations of the body-scale relationship were made from 608 specimens taken from Pools 3, 4A, 5A, 6, 8, 9, 10, and 11 during the summer of 1948. Key scales were mounted in glycerin-gelatin. Various types of gear (trot line, trap net, hoop net, trammel net, gill net, minnow seine, trawl, and shore seine) were used in obtaining the samples. The fish from the 1947 sample were taken in the commercial fisheries, and for the most part were not sexed. Total measurements recorded to the nearest tenth of an inch were used exclusively. Growth analysis was made in the manner outlined by Hile (1941).

ASSESSMENT OF AGE

Age of each fish was determined from observations made on at least two scales. It was essential in the assessment of age to determine whether the annulus for the year of collection had formed. The criteria given by Hansen (1937) coupled with careful observation of the scale sculpturing were used to determine whether or not the annulus for the current growing season had formed. The time of the annulus formation in 1946 covered the period from May 1 to July 1, and in 1948 the period covered the time from May 16 to July 16. Those individuals for which positive assessment of age could not be made were excluded from the calculations.

The difficulty experienced by other workers in aging the scales from mature specimens was also encountered by the authors. It was imperative, therefore, that no confidence be placed in the calculations until age assessment was validated. Three criteria of validity were used: (1) increase of total length with increase in assessed age, (2) similarity in trend of percentage deviation of growth in different calendar years for those individuals of the same year classes taken in two different years of collection, and (3) agreement among different year classes as to goodness or poorness of growth in different calendar years. An increase of the grand average calculated length with a corresponding increase in age (Table 1, Fig. 1) indicates that there is an increase in the number of annuli with a corresponding increase in total body length. At age I the calculated length was 4.9 inches and it increased for each succeeding assessed year through age IX, at which time the calculated length was 21.3 inches. The best evidence of accurate age determination was the agreement of the percentage deviations from the mean annual growth of individuals of year classes 1940 through 1945 taken in two different years of collection, 1946 and 1948 (Table 2). During 1940 and 1941 the percentage deviation from average growth of the period 1940 to 1945 was positive. In 1942 and 1943 the percentage deviation was negative, followed by a positive deviation in 1944. Growth for the same year classes dropped considerably during 1945. If the aging of the same year classes taken in 1946 and 1948 had not been consistent, the trends in percentage deviation of growth would not have been in agreement. Further validation is demonstrated in the goodness or poorness of growth of all age groups for each calendar year (Table 3). Growth made by age groups II and III was slower in 1942 than in 1941. Age groups II, III, and IV made progressively better growth in 1943 and 1944, but dropped in 1945. Slight discrepancies of the growth pattern for age groups IV, V, and VI probably reflect variations in growth during the period of maturation.

Table 1.—*The grand average calculated length in inches at the end of each year of growth for the year classes 1936 through 1938 and the year classes of 1939 through 1947.*

	Year Classes			
	1936-1938		1939-1947	
Age	Number of fish	Calculated length	Number of fish	Calculated length
XI	1	24.2	....	....
X	3	24.1	....	....
IX	5	23.1	1	21.3
VIII	11	21.2	7	19.1
VII	11	19.8	31	18.1
VI	11	18.4	89	16.5
V	11	16.6	273	14.8
IV	11	14.8	400	13.4
III	11	12.7	521	11.7
II	11	9.4	642	9.0
I	11	4.7	891	4.9

CALCULATED GROWTH

Body length at time of scale formation.—A careful study of four age class 0 fish collected in 1948 aided in the determination of the length of the body at the time of scale formation. Scalation of the caudal peduncle had been completed on all four specimens, but the anterior scalation differed. The variations in degree of scalation with variation in length provides evidence that scale formation is progressive, first forming on the peduncle and then developing anteriorly along the lateral line. From the lateral line scalation proceeds dorsally and ventrally. Variation in the degree of scalation is not consistent with an increase in length. In one specimen of 20 millimeters total length, the peduncle was completely scaled, and an area of six to eight rows of scales extended to the head region along the lateral line. The peduncle and an anterior portion extending to the region touched by the posterior extension of the pectoral fin was scaled in one specimen of 24 millimeters. Possible discrepancies of observation due to the loss of scales in handling were eliminated by observing the scale pockets of the epidermal layer. Fish (1932) gives no indication of the scale development for specimens having a total length of 13.3 and 15.6 millimeters. Pearson (1930) describes a 25 millimeter specimen of *Sciaenops ocellatus*, the red fish, as having scales and teeth. *Micropogon undulatus*, the croaker, another relative of the sheepshead, is illustrated as having scales at 32 millimeters total length (Hildebrand and Cable, 1930). For purposes of growth calculations, 20 millimeters was assumed to be the length at time of scale formation. This

TABLE 2.—*The percentage deviation of annual growth from the mean growth of the years 1940 to 1945 of those individuals of the same year classes taken in two different years of collection, 1946 and 1948.*

Year of collection	Calendar year					
	1940	1941	1942	1943	1944	1945
1946	+0.2	+0.2	—4.3	—5.3	+9.7	—0.4
1948	+1.8	+8.3	—3.4	—3.4	+5.4	—6.7

TABLE 3.—*The mean annual increment of all year classes for each calendar year. Change in increment from previous year indicated by plus or minus. Expressed in millimeters.*

Number of fish	Age	Mean annual increment								
		1939	1940	1941	1942	1943	1944	1945	1946	1947
1	IX									.8
7	VIII								1.9	1.0—
31	VII							1.2	1.5+	1.5
89	VI						1.5	1.4—	1.4	1.8+
273	V					2.0	1.5—	1.7+	.9—	1.8+
400	IV				1.8	1.9+	2.0+	1.8—	1.7—	2.1+
521	III			2.9	2.5—	2.7+	2.8+	2.6—	2.8+	3.2+
642	II		4.3	4.5+	3.7—	4.0+	4.4+	4.2—	5.4+	4.3—
891	I	4.9	4.6—	4.7+	4.8+	4.6—	5.3+	4.0—	5.1+	5.2+

value represented the midpoint between lengths at which no scales were present (Fish, 1932) and the length at which scales were present within the general area of sampling shown in the 24-millimeter specimen taken in 1948.

Body-scale relationship.—The relationship of the length of the anterior radius of the key scale to the total length of the fish was based upon the measurements of 608 specimens representing lengths of 1.6 to 23.2 inches. Calculation of the line of best fit by least squares gives a line defined by the formula, $Y = 1.20x - 11.97$, where Y represents the magnified length (25.5x) of the anterior radius of the key scale in millimeters, and x represents the total length of the fish in inches. The calculated line for the females can be expressed as $Y = 1.23x - 18.17$, and that for the males as $Y = 1.25x - 15.93$. It can be seen that the males and females are not sufficiently different to justify separate consideration. It is interesting to note that a backward extension of the regression line of body-scale relationship intercepts the abscissa at a point (1 inch) which is slightly in excess of the value of the assumed body length at time of scale formation. A curvilinear relationship between the body and scale lengths is suggested in the very small fish but is of no importance in general growth calculations.

The average calculated length at the end of each year of growth.—The calculations of length at succeeding annuli were made from measurements of the anterior radius applied in the formula

$$L_1 = C + \frac{S_1}{S} (L - C),$$

where L_1 is the length of the fish at the time of each annulus formation, C is the length of the fish at the time of scale formation, S_1 is the length of the anterior radius of the scale at each annulus, S is the length of the anterior radius at capture, and L is the total length of the fish at time of capture. Measurements of two scales from each fish were used to reduce the influence of the variability of measurements observed from scale to scale. The grand average calculated length was determined for each year of growth from all specimens which had completed growth for any year represented in the calculations (Table 1, Fig. 1).

Differences of growth rates between the 1936 through 1938 year classes and the 1939 through 1947 year classes suggested the necessity of separate consideration of the 1936-1938 year classes. The year classes of 1936, 1937, and 1938 which were spawned coincidentally with or immediately following impoundment have been considered in separate calculations because they reflect unstable growth conditions. Inclusion of these first three year classes in the total calculations would give a bias indicating better growth than has actually existed over the greater part of the period represented by available samples. The excellent growth made in the early years of impoundment has not been maintained or even equaled. Growth of subsequent year classes has been variable around a lower mean value.

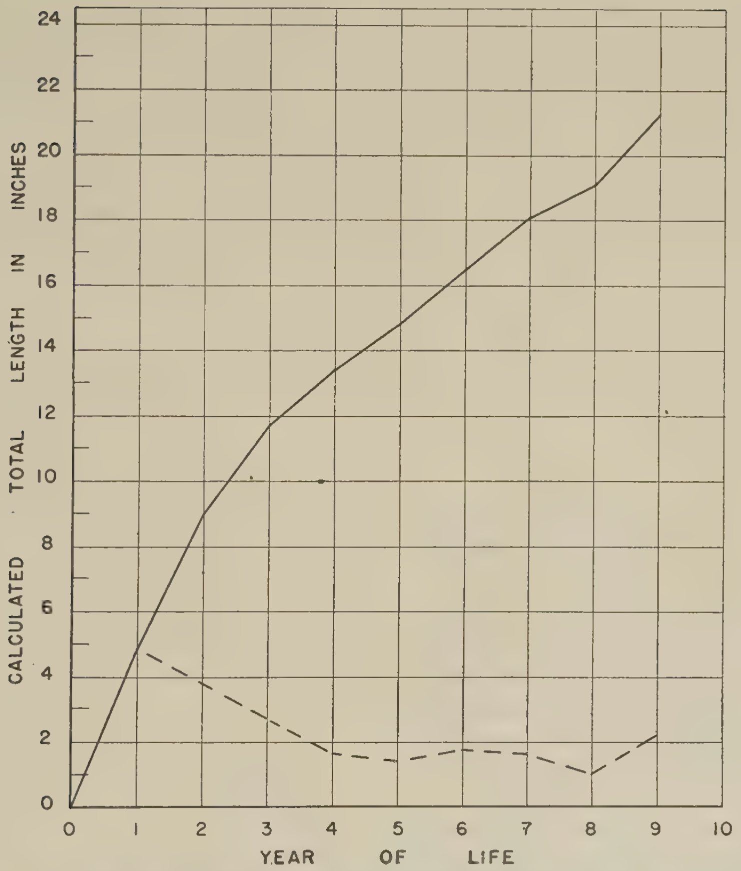

FIGURE 1.—The grand average calculated length at the end of each year of growth for the year classes 1939 through 1947 and the corresponding increment of growth for each year. Solid line represents length and broken line represents annual increment.

The grand average calculated length for sheepshead at the end of 1 year was 4.9 inches (Table 1, Fig. 1). It appears that differences in the growth rate for the first year under different conditions or in different bodies of water are small (Tables 1 and 4). During the second year the calculations show a growth increment of 4.1 inches resulting in a total length of 9.0 inches. At the end of the third year an increment of 2.7 inches gave a calculated length of 11.7 inches. The calculated length at the end of the fourth year gave a total length of 13.4 inches with an increment of 1.7 inches. The greatest yearly increments of growth were made during the first four years of life after which time the annual growth varied between 1.0 and 1.7 inches. The grand average calculated length at the end of 8 years was 19.1 inches. The value for the ninth year based upon one specimen cannot be considered representative. There were slight differences in the grand average calculated lengths between the male and female.. Differences in growth, when a summation of the mean annual increments was made (Table 4), did not exceed 3 percent of the calculated length at any one age.

TABLE 4.—*The total length in inches of male and female sheepshead in the upper Mississippi River at end of each year of life calculated from summation of mean annual increments.*

Age	Males		Females	
	Number of fish	Summation of increments	Number of fish	Summation of increments
IX	...	...	1	20.6
VIII	2	19.3	5	19.8
VII	6	18.2	19	18.2
VI	15	16.8	57	16.9
V	50	15.3	137	15.4
IV	91	13.8	195	13.8
III	136	12.1	250	11.8
II	187	9.2	312	9.1
I	216	4.6	354	4.8

Some commercial fishermen believe that the largest fish are taken in the immediate area of impoundment. Analysis of the catch from Pools 8 and 10 did not verify these general observations. Larger fish were taken at the dam than in the non-impounded area of Pool 10, but larger fish and a greater abundance of large fish were taken in the river at LaCrosse, approximately 10 miles above the dam of Pool 8. Five stations within Pools 8 and 10 were calculated separately to check the apparent difference in sizes of fish taken in various parts of the same pool. Growth in the impounded area of Pool 8, at Stoddard, Wisconsin, was essentially the same for the first 4 years as the growth in the upstream section at LaCrosse, Wisconsin. A slight divergence of calculated growth was noted after the fourth year, but this difference is believed to result from sampling error. Sheepshead taken from Pool 10 at Harpers Ferry and McGregor in the open river grew at a slightly slower rate than those from the impounded area at Guttenberg. Areas of impoundment, therefore, may or may not be areas in which superior growth is made.

Growth was not only considered from station to station within each pool, but was also considered separately from pool to pool to determine the importance of latitude as a factor in growth. In Pool 17 at Muscatine, Iowa, 2- and 3-year-old sheepshead grew more slowly than the same age groups in Pools 4, 8, and 10. Superior growth was indicated by the fish of Pool 8. Since the percentage differences of growth within the pools and from pool to pool were not significant, latitude within the section of the river studied does not appear to influence growth rate.

The growth rates of Mississippi River and Lake Erie sheepshead.—Growth rate of Lake Erie sheepshead (Van Oosten, 1938) is below that of these fish in the upper Mississippi River (Table 5). With the exception of the fourth year of growth the Mississippi River sheepshead show progressively better growth during the 7 years which have been compared. Differences in the calculated length of fish from the two bodies of water began with a 0.9-inch difference in the second year and progressed to a difference of 2.3 inches in the seventh year, at which time the Mississippi River sheepshead were 18.1 inches and the Lake Erie sheepshead were 15.8 inches.

TABLE 5.—*A comparison of the grand average calculated length in inches at the formation of each annulus for sheepshead from the Mississippi River and Lake Erie.*

Water	Age							
	I	II	III	IV	V	VI	VII	VIII
Mississippi River...	4.9	9.0	11.7	13.4	14.8	16.5	18.1	19.1
Lake Erie[1]........	4.8	8.1	10.2	12.0	13.3	14.8	15.8	....

[1] Van Oosten (1938).

Growth in different calendar years.—Growth calculations indicated considerable differences in rates of increment from year to year. An analysis of the percentage deviation of growth for each year from the average growth of the period 1939 to 1947, following the methods of Hile (1941), is as follows:

1939	1940	1941	1942	1943	1944	1945	1946	1947
+7.8	+1.5	+4.4	—4.7	—1.6	+3.5	—7.3	+2.3	+1.3

The best growth occurred in 1939 and the poorest in 1945. Exceptional growth for the year of 1939 may be in part the result of the recent impoundment. An analysis of the daily water levels of Lake Pepin (Pool 4A) during the ice-free seasons of 1939 through 1947 showed no consistent relationship between growth rate and average annual water level.

AGE AT MATURITY

Observed differences in lengths and ages of mature males and females suggested a critical study of age at maturity. The fish examined for age at maturity were also used to determine the average length of spawning season. The period of spawning was determined from the occurrence in daily catches of specimens which were ready to spawn. The age at maturity was based upon gross observation of gonadal condition as to "ripe," gonad distended, but not spawned; "ripe+," spawn or milt readily removed; and "spent," gonad flaccid, occasionally showing small traces of ova or milt. Immature condition was characterized by a thin translucent gonad, There is a marked difference between the male and female sheepshead in the age and length at maturity (Table 6). The first mature males were observed during their third season of growth and had a mean length of 12.2 inches, 3.2 inches greater than the average length for fish of age II. During the fourth season of growth 63.4 percent were mature and had as a mean length 13.8 inches, 2.1 inches greater than the average length for fish of corresponding age. Maturity was reached by 97 percent of the males in their fifth season of growth, but all were not mature until the seventh season of growth. Maturity in the females was first observed in fish during their fifth growing season at which itme 46 percent were mature. Their average length was 15.2 inches, 1.8 inches greater than the average length of all 4-year-old fish. A maturity of 100 percent was shown in the females beyond the sixth season of growth. These data indicate that individuals of superior growth reach maturity 1 to 3 years earlier than other members of the same year class, and that the males mature 2 years prior to the females.

TABLE 6.—*The percentage of mature males and females in various age groups with average length of mature fish in each group compared to average length of entire age class. Lengths expressed in inches.*

Age	Grand average calculated length	Males			Females		
		Number	Average length	Percentage mature	Number	Average length	Percentage mature
I.	4.9	..	....	0.0	..	...	0.0
II.	9.0	43	12.2	23.2	61	....	0.0
III.	11.7	41	13.8	63.4	48	....	0.0
IV.	13.4	36	14.1	97.2	39	15.2	46.1
V.	14.8	31	14.7	96.8	58	15.5	48.3
VI.	16.5	10	16.1	100	30	16.7	96.6
VII.	18.1	..	....	....	11	17.9	100

Mature individuals with "ripe+" gonads were taken in greatest numbers during the last 2 weeks in May of 1946. The last individuals observed in this condition were taken during the first 2 weeks of June. Several specimens were observed as "ripe" 2 weeks after the last "ripe+" fish were taken. It is believed that these represent unspawned individuals which had retained their sperm and ova. It appeared that the first 2 weeks in June of 1948 represented the height of the spawning season for that year, and that it was terminated by mid-July. In general the spawning period extends from the first of May to the last of June.

CONCLUSIONS

A study of the yearly growth increment without considering natural mortality shows that optimum size at harvest is well above the size utilized by the commercial markets (11 to 16 inches or ¾ to 2 pounds). Their utilization at a more productive size is prevented because of the inferior quality of larger sheepshead. At 16 inches 50 percent of the females are mature but the harvest of fish at desirable market size prevents the attainment of sexual maturity for most individuals. Should the necessity of increasing spawning stock arise it would be essential that minimum size limits be considered. The similarity of growth pattern within the pools from Lake Pepin to Muscatine, Iowa, suggests the necessity for uniform regulations for the sheepshead in this area.

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THE EFFECT OF KRAFT PULP MILL WASTES ON SOME AQUATIC ORGANISMS

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Abstract

A study has been made of the toxic substances which may be found in kraft pulp-mill waste-waters. It has been determined that the sulphides, mercaptans, resin acid soaps, and sodium hydroxide constitute the greatest hazard. The minimum lethal concentration of these and other materials to fresh-water minnows, *Daphnia*, and aquatic insect larvae has been established. Methods have been devised for evaluating these materials in kraft-waste waters, and data from the examination of the wastes of a typical northern kraft mill are presented.

Introduction

The pulp and paper industry has for years been interested in problems relating to stream improvement since large amounts of water are required in the making of its products. This water is not a part of the final product but is used, among other ways, as a medium for pulp refining and sheet formation. During its use, solids are added to it, either in solution or suspension, and when, after its use, the water is returned to the stream, these solids can have an adverse effect on the stream.

There are at least three ways by which any industrial or domestic waste can affect the aquatic environment. First, the waste may contain toxic substances which will destroy the fauna and/or flora; second, it may contain materials in solution, the stabilization of which uses so much oxygen that the aquatic forms are adversely affected; and third, there may be a combination of these two types of action.

In the current study, attention has been directed to the first of these three possibilities in relation to kraft mill operation. Until recently this problem has received comparatively little attention. Cole (1935) investigated the effects of kraft black liquor on perch, bluegills, largemouth black bass, and rock bass, and found that the material was harmless in concentrations up to 5,000 p.p.m. In Scandinavia, Bergström and Vallin (1937) and Bergström (1939) studied the effect on fish of various components of kraft mill effluents, including digester condensates, dilute wash waters, and other wastes. He found that, of all the sources of waste arising from the kraft process, those containing the sulphate soap carried the greatest potential danger. This same fact had been reported earlier by Ebeling (1931). Hagman (1936) found that resin acids in sufficient concentrations would harm fish, and stated that the safe concentration of these acids was 2 p.p.m. or less. Extrom and Farner (1943) concluded that bass *(Huro salmoides)*, bluegills *(Lepomis macrochirus)*, and sunfish *(Lepomis gibbosus)* were unaffected by "river concentrations" of kraft mill wastes although the fish could not live in the wastes themselves.

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The inconclusive nature of the work cited above, together with the need for more specific information, impelled segments of the kraft pulping industry to conduct and support an investigation designed to clarify the entire relationship between the kraft mill and the stream. Accordingly, the work started by Cole and continued by Extrom and Farner was brought to The Institute of Paper Chemistry in 1943. At the Institute, the study was first supported by the Committee on Kraft Waste Disposal, a group representing various kraft mills in Wisconsin. For the past 5 years, however, the investigation has been supported and extended by the National Council for Stream Improvement, Inc. (an organization of pulp and paper companies) whose purpose is to study this and other pollution problems in the pulp and paper industry. The objectives of the present investigation may be listed as follows: (1) to determine if and to what extent the waste liquors from a kraft mill are toxic to aquatic organisms; (2) to devise methods for the detection and measurement of these toxic components; and (3) to discover measures which will prevent these wastes from reaching the streams.

There are several ways by which chemical wood pulp can be manufactured, among which are the sulphite process, the kraft or sulphate process and, more recently, the semichemical process. Of these the kraft method is the most widely used, with the sulphite process second in importance. In the sulphite process the liquor used for digesting the wood is an aqueous solution of sulphurous acid in which lime or some other base has been dissolved. The result is, therefore, a solution of a bisulphite of the base containing an excess of sulphurous acid. When calcium[1] is used as the base, the nature of this liquor, as well as the mechanics of the sulphite process, makes it economically unfeasible to recover the spent liquor. It is, therefore, wasted and is commonly known as sulphite waste liquor.

In the kraft process, on the other hand, the wood is cooked or digested with an alkaline liquor in which the principal components are sodium hydroxide and sodium sulphide, the latter comprising up to 45 percent of the total alkali. From the point of view of the problem at hand, the important aspect of the kraft process is that instead of being wasted the spent liquor is evaporated and burned, and the chemicals in the ash are re-used and the heat is recovered.

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[1] In recent years the Weyerhaeuser Timber Company has developed an acid cooking process in which magnesium instead of calcium is used. In theory, this process permits the recovery of the chemicals and burning of the residue for heat recovery, thus materially reducing, if not eliminating, the problem of stream pollution. However, this development is still in the experimental stage.

In order to delineate more clearly the problem of stream pollution which may result from a kraft mill, it is desirable to consider briefly the general aspects of the process. The wood is cut into small chips and introduced into digesters, the cooking liquor is added, and the digester closed. Heat is then applied gradually, by direct or indirect steaming, and the cooking process is started.

The cooking cycle of any type of chemical pulp production consists of three phases: (1) a period when the liquor is permeating the chips, (2) a period of full pressure when the cellulose fibers are being freed from their bonding material, and (3) a gassing-down period after the cook when the digester's internal pressure is gradually relieved to the point where the pulp can be blown out. At the conclusion of the first phase, the accumulated air and other gases in the digester are drawn off and passed through a condenser for heat recovery. Turpentine is recovered from the condensate, and the residue becomes waste. Similarly, at the conclusion of the second phase, the relief gases are condensed and may become waste.

After the pulp is blown from the digester, the spent cooking liquor (black liquor) is separated from it and sent to the recovery plant. The pulp is washed with water that is re-used until the black liquor concentration is high enough for wash waters to be sent to the recovery plant. In the final washing process, however, the waters may be so dilute that their chemicals cannot be recovered economically and, therefore, they may be sent to the sewer.

The spent cooking liquor and the concentrated wash waters are evaporated under vacuum to a consistency of approximately 50 percent solids. In most mills this vacuum is produced by a jet condenser and its effluent may contain in solution some of the non-condensable gases from the process of black liquor evaporation. This effluent may be sent to the sewer or, in some mills, it is used for pulp washing and eventually finds its way back to the recovery plant. Use of surface condensers instead of the jet type will reduce, if not eliminate, the possibility of pollution from this source. The concentrated black liquor, containing most of the non-fibrous portion of the original wood as well as the spent chemicals, is then burned in furnaces designed to recover the chemicals and the heat of combustion.

When the black liquor from the blowpits (into which it is blown from the digester) is sent to the recovery plant, it is usually stored in large receptacles for varying periods. As the material stands, a thick foamy material, called sulphate soap, rises to the surface. Actually, it is composed of the sodium salts of resin and fatty acids which were present in the wood. Currently, this soap is being recovered and sold, but small amounts of it may be found in the dilute wash water.

In summary, it can be stated that the major potential stream polluting products from the normal operation of a kraft mill are: (1) the initial blowdown condensate, (2) the final blowdown condensate, (3) the evaporator condensate, and (4) the soaps and other material in the dilute wash waters.

METHOD OF TESTING TOXICITY OF WASTES

According to Sutermeister (1941), kraft waste liquors may contain the following compounds: sodium carbonate, sodium hydroxide, sodium sulphide, sodium sulphate, sodium sulphite, sodium chloride, hydrogen sulphide, methyl mercaptan, and sodium combined with organic acids, such as the sodium salts of resin and fatty acids (soaps). It is apparent that any of these compounds might prove toxic if they are present in sufficient amounts. The first problem, therefore, was to determine the minimum lethal concentration of these materials to various aquatic species.

In choosing test animals, the more susceptible species of each group were selected. A secondary consideration was the environmental relationship of the groups, i.e., fish and fish-food organisms. The fish used were species of minnows taken from various sources in the vicinity of Appleton, Wisconsin. Lake Emerald *(Notropis a. atherinoides)* and spotfin *(Notropis spilopterus)* shiners were most commonly used but, at times, the bluntnose minnow *(Hyborhyncus notatus)* and the rosyface shiner *(Notropis rubellus)* were also used. Two types of fish-food organisms were used as test animals. The first of these was *Daphnia sp.* grown in the laboratory for the purpose, and the second was aquatic insect larvae of various species taken from Lake Winnebago and adjacent waters.

The method using minnows as test animals was a modification of that employed by Powers (1917) and has been previously described by the senior author (Van Horn, 1943). Two-liter portions of the materials to be tested were placed in open battery jars immersed in a constant temperature (18° C.) water bath. From one to five fish, depending on the oxygen resources of the test solution, were then placed in each jar, and observations were made hourly up to 5 days. The survival time of the fish was recorded if death resulted. Checks were made on the dissolved-oxygen content of the test solution at the conclusion of the test and, in those cases where this level fell below 4 p.p.m., the data were discarded. Checks were also made on pH and alkalinity to make sure that the conditions were within limits favorable to fish life. If these conditions fell outside of these limits, which was very seldom, the results were discarded.

When *Daphnia* was used as the test animal, two specimens were placed in a vial containing 25 milliliters of the test solution. The vials were held in racks, each of which carried 26 test vials and 6 controls. Periodic observations were made for a period of 48 hours, and the length of time elapsing between the time of placing the specimens in the solution and immobilization was recorded. Checks on dissolved oxygen, pH, and alkalinity were made before and after each test.

When aquatic insect larvae were employed as test animals, the method used for *Daphnia* was modified to accommodate the physiological requirements of the insect larvae. The larvae were placed in test solutions contained in glass vessels of suitable size and were permitted to remain there for a period of 48 hours. In the meantime, a close watch was kept on them. Extraneous variables, such as pH, alkalinity, and dissolved oxygen, were checked as described above. The species used in these studies were taken from Lake Winnebago and adjacent waters and included mayflies of the genus *Blasturus* and *Leptophlebia*, the damsel fly *Agrion*, and the dipteran *Chironomus*. All tests were made using stabilized Fox River water. This water is relatively hard, having a pH of 7.6 to 7.8 and a total alkalinity of from 140 to 160 p.p.m.

TOXICITY OF KRAFT MILL WASTES

In order to determine which of the components of a typical kraft mill waste would be significant in this study, a number of screening tests were made on 15 compounds, using the Lake Emerald and spotfin shiners as test animals (Table 1). It is apparent that the compounds of greatest interest in this study are sodium hydroxide, the sulphides, methyl mercaptan, and the crude sulphate soap and its components. Furthermore, under normal operating conditions, kraft waste waters are relatively constant in their composition and in the proportion of one component to another. For these reasons, particular attention was directed to the four compounds indicated, and an extensive series of tests, in addition

TABLE 1.—*Minimum lethal concentrations*[1] *of kraft pulp-mill waste components killing Lake Emerald and spotfin shiners in 120 hours.*

Compound	Concentration, p.p.m.
Sodium hydroxide	100.0
Sodium sulphide	3.0
Methyl mercaptan	0.5
Hydrogen sulphide	1.0
Sodium thiosulphate	5.0
Sodium chloride	2,500.0
Sodium carbonate	250.0
Sodium sulphate	100.0
Formaldehyde	50.0
Crude sulphate soap	5.0
Sodium salt of fatty acid fraction of crude soap	5.0
Sodium salt of resin acid fraction of crude soap	1.0
Sodium oleate (stock room)	5.0
Phytosterol (pure)	3.0
Sodium abietate (pure)	3.0

[1] In this work the "minimum lethal concentration" was defined as the lowest concentration of a toxic material which would kill any of the test animals within a period of 120 hours, when held in a test solution at 18° C., and factors of pH, total alkalinity, and dissolved oxygen being held to conditions approximating those of control tests. 100 percent survival of controls was required.

to those just described for minnows, was made on *Daphnia* and two species of aquatic insect larvae.

The data contained in Table 2 indicate that the minimum lethal concentration was roughly the same for the species of minnows tested, *Daphnia*, and the mayfly larvae. While mayfly larvae were less sensitive to soap (10 p.p.m.), they were more sensitive than either of the other forms to sodium sulphide. The midge larvae (*Chironomus* sp.) are much less sensitive to all the toxic compounds tested.

TABLE 2.—*The minimum lethal concentrations of kraft pulp waste components affecting minnows,*[1] *Daphnia, and two species of aquatic insect larvae.*[2]

Compound	Minimum Lethal Concentration, p.p.m.			
	Minnows	*Daphnia*	Mayfly Larvae[2]	*Chironomus* Larvae
Sodium hydroxide	100.0	100.0	100.0	700.0
Sodium sulphide	3.0	10.0	1.0	1,000.0
Hydrogen sulphide	1.0	1.0	1.0	750.0
Methyl mercaptan	0.5	1.0	1.0	50.0
Crude sulphate soap	5.0	5.0	10.0	50.0
Sodium salt of resin acid fraction of soap	1.0	3.0	....	50.0
Sodium salt of fatty acid fraction of soap	5.0	1.0	....	....

[1] The spotfin shiner *(Notropis spilopterus)* and the Lake Emerald shiner *(Notropis a. atherinoides)*.
[2] Mayfly larvae used were of the genera *Blasturus* and *Leptophlebia*. No attempt was made to determine species.

QUANTITY OF TOXIC MATERIALS IN WASTE WATER

Having established the maximum safe concentration of the potentially toxic materials found in kraft pulping wastes, the next step was to measure the amount passing to the streams. The methods of analysis adopted are being reported in detail elsewhere but they may be briefly described here.

It was apparent that the various sulphides need not be determined individually and, for the sake of convenience, it would be better if the sulphides could be collectively evaluated by a single analysis. Tamele and Ryland (1936), Tamele, *et al.* (1941), Lykken and Truemmler (1942), and Borlew and Pascoe (1946) have described such a method which involves the use of a potentiometric-argentimetric titration in a highly alkaline solution. The applicability of this method was thoroughly explored, and it was determined that it would be effective in the current problem. Furthermore, if chlorides are not present in any great amount, it is possible to use the same titration for mercaptan evaluation. For the resin acids, an adaptation of the Liebermann reaction was used. The sodium hydroxide analysis consisted of a simple potentiometric titration with a weak acid to a pH of 8.4.

During the period from May to September, 1947, the waste waters of five typical northern kraft mills were subjected to frequent analyses for sulphides, mercaptans, resin soaps, sodium hydroxide, and pH. Care was taken to sample under all types of operating conditions. All samples taken were grab samples. It should be noted that 24-hour composite samples of these wastes will not show extremes in variation of their chemical content. It has been demonstrated, for example, that, if a sample having a high pH is permitted to stand for an hour or so, its pH will gradually change in the direction of neutrality. For that reason, grab samples were taken to determine the degree of variation in the nature of the waste waters. At the time the samples were taken, data on the volume of sewer discharge and the volume of river discharge were secured. A typical analysis for one mill is shown in Table 3.

It will be noted from Table 3 that, in 13 of the 35 analyses of raw waste, the concentration of sulphides in the waste water exceeded the minimum lethal concentration (1 p.p.m.) ; in all cases, the concentration of mercaptans exceeds the minimum lethal concentration (0.5 p.p.m.) ; in all cases, content of the resin acid soaps exceeded the minimum lethal concentration (1 p.p.m.) ; and, in 4 of the 35 analyses, the concentration

TABLE 3.—*The results of waste water analyses of a typical northern kraft mill. June 24 to September 12, 1947.*

Sample No.	River dilution ratio[1]	Parts per Million				
		Sulphides	Mercaptans	Resin soaps	Sodium hydroxide	pH
1	170	0.7	1.5	5.0	6.6	8.6
2	166	0.6	0.7	5.0	8.0	8.8
3	178	1.5	4.1	18.0	61.4	9.9
4	218	1.6	1.8	8.0	24.2	9.4
5	185	1.0	1.2	5.0	12.0	9.0
6	193	0.2	1.9	5.0	0.0	7.8
7	275	18.4	12.0	18.0	114.0	10.6
8	232	0.5	2.5	3.0	6.6	8.7
9	224	0.2	0.7	3.0	0.0	8.2
10	138	0.4	0.9	2.0	0.0	8.2
11	142	0.9	1.6	3.0	0.0	8.2
12	126	0.0	1.0	3.0	0.0	8.1
13	123	0.8	1.6	3.0	14.7	8.7
14	193	0.0	2.7	5.0	10.6	8.7
15	173	0.2	1.4	5.0	0.0	8.3
16	191	0.2	0.9	5.0	14.7	8.8
17	173	0.2	1.2	2.0	0.0	7.6
18	176	0.0	1.1	5.0	0.0	7.9
19	166	0.0	1.2	3.0	0.0	7.9
20	177	0.2	1.1	3.0	0.0	7.7
21	153	0.2	1.1	3.0	0.0	8.4
22	152	0.0	0.8	3.0	0.0	8.1
23	157	0.0	0.6	2.0	0.0	8.3
24	144	0.3	1.0	2.0	2.6	8.5
25	156	2.1	1.9	3.0	13.3	8.9
26	161	88.4	15.8	18.0	391.0	10.5
27	113	0.4	1.6	3.0	4.0	8.5
28	103	0.3	1.7	3.0	17.3	9.0
29	96	0.0	3.1	5.1	9.3	8.7
30	94	2.8	3.3	8.0	21.4	8.8
31	94	25.8	8.1	18.0	115.0	9.4
32	134	0.4	1.0	3.0	144.0	10.7
33	136	3.6	5.1	5.0	13.7	8.9
34	127	2.8	7.2	3.0	9.4	8.8
35	109	1.3	0.9	5.0	0.2	8.5

[1] The river dilution ratio is calculated by dividing the volume of river discharge by the volume of sewer discharge.

of sodium hydroxide exceeded the minimum lethal concentration (100 p.p.m.). As soon as the wastes are discharged, dilution with river water takes place at varying rates depending on the volume of river flow. The lowest dilution ratio observed at this particular mill was 1 to 94 (Table 3). If total dilution is assumed, the concentrations of the toxic materials would be brought to a point below their minimum lethal concentration as soon as the necessary dilution had occurred.

In the entire study, including phases not presented here, the lowest ratio of dilution found in the two receiving streams was 1 to 73. Similarly, the highest concentrations of the compounds under study were sulphides 88.4 p.p.m., mercaptans 45 p.p.m., resin acid soaps 28 p.p.m., and sodium hydroxide 3,763 p.p.m. Although these conditions did not occur simultaneously, they do form a theoretical picture of what could happen under the worst conditions in the mills under study. In each case, however, the concentrations of the materials after dilution are brought to a point where their danger is reduced to a minimum, if not eliminated.

DISCUSSION

The primary purpose of this investigation was to determine whether or not a problem relating to aquatic organism toxicity is associated with the normal operation of a kraft pulp mill and, if there is a problem, to determine its seriousness. From the data presented it can be stated that, under normal operating conditions in the locality where the study was made, there is little danger to the aquatic environment from the toxic properties of kraft pulp-mill wastes. While the majority of analyses of waste waters indicated that they contained toxic materials in excess of their minimum lethal concentration, their concentration was reduced to a level safe for fish and other forms after dilution in the stream. It should be pointed out also that, when fish or other aquatic organisms come into contact with these materials in lower concentrations, death does not occur instantly. For example, in a concentration of methyl mercaptan of 1 p.p.m. (twice the minimum lethal concentration), fish may live for as long as 2 days before exhibiting any of the reactions of poisoning.

If a kraft pulp mill is operating normally, there seems little danger that it may be responsible for destroying an aquatic environment by the toxic action of its wastes, providing enough receiving water is available for sufficient dilution. Abnormal or accidental incidents may sometimes occur in the operation of any industrial installation. For that reason, this investigation is being continued to determine at which step in the operation the potentially toxic materials occur, and to find ways and means of preventing their passage to the stream in the event of accidents or other abnormal conditions.

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USE OF FISH FOR THE OLFACTORY ASSAY OF POLLUTANTS (PHENOLS) IN WATER[1]

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Abstract

Phenol, a common pollutant in municipal water supplies, cannot be readily detected in low concentrations until it has reacted with chlorine forming odorous chlorophenols. A method is here presented whereby bluntnose minnows (*Hyborhynchus notatus*) are used to detect the presence of phenols below the threshold for man (0.01 p.p.m.). Fishes of two aquaria were trained to associate the odor of phenol with food; the odor of a p-chlorophenol with punishment. The minnows of two other aquaria were trained to the same two odors, but with reverse meanings. Upon completion of the training period, the minnows were discriminating successfully between these two substances at concentrations of at most 0.0005 p.p.m. A generalization test, using o-chlorophenol as the third odor, indicated that the fishes were able to distinguish it from the two training odors. The biological assay of phenolic compounds by this method is primarily one of detection and not of quantitative analysis.

Introduction

That fishes detect odors emitted from aquatic plants was demonstrated recently (Walker and Hasler, 1949). Previous investigations have shown that fishes perceive scents produced by their own kind (Goez, 1941; Strieck, 1924; v. Frisch, 1941; Wrede, 1932). It appears likely, therefore, that natural odors may play an important role in the life of a fish. Among other possible roles, they may aid in: (1) feeding and seeking cover at night or under other adverse visual conditions, and (2) orienting to characteristic odors of streams during migration. Fishes in polluted habitats are also confronted with unnatural odors, such as those produced by industrial wastes. The object of the present work was to determine the capacity of fishes to detect odors of such pollutants. It was hoped that, if fishes could perceive odors of dilute solutions of a waste, they could be trained for immediate assay of a substance present in a concentration not easily detected by chemical analyses. More specifically, a municipal water treatment plant often has the practical problem of chlorinating water which contains phenol. The chlorophenols formed have distinctive medicinal odors and often a public nuisance arises before sufficient chlorine can be added to break down the chlorophenols to a point where they can no longer be detected as tastes or odors by man.

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Organic wastes which have offensive odors are commonly classified as phenolic and non-phenolic (Buswell, 1947). Typical examples of phenolic waste industries are phenol, dye, medicinals, plastics, coke, charcoal, cresols, acids, tar refineries, oil refineries, producers of crude oil, road oil, and gas liquor (ammonia recovery plants).

Chemical tests for determination of the phenols produced by these industries are cumbersome and slow. The threshold odor test (A.P.H.A., 1946) utilizes the olfactory capacity of humans to detect odors in drinking water. However, 0.01 p.p.m. is the lowest dilution in which phenol can usually be detected. Moreover, different persons react variably to the same concentration of odor and, in addition, the threshold of an individual may change from time to time. There is a need for a fast, reliable method of testing which will detect odors below the human threshold.

METHODS AND MATERIALS

The purpose of this experiment was to obtain an olfactory discrimination between phenol and p-chlorophenol by the bluntnose minnow, *Hyborhynchus notatus* (Raf.). The minnows were trained to associate the odor of one of the substances with food; the odor of the other with punishment.

The equipment used by Walker and Hasler (1949) was suitable for conducting this series of training tests. It consisted of several 7-gallon aquaria, each with a siphon-airlift circulation system installed in both ends (Figure 1). Water was siphoned from the aquarium, returned by air pressure, and discharged into a 6-inch funnel which was suspended above the tank. The funnel was connected to a glass tube which lay across the end of the aquarium. Perforations in the tube directed the incoming water across the bottom of the aquarium. Water from the jet on one side flowed only about half way across, because there it met the stream from the other end, and both were deflected upward. This produced two currents or convection cells, each of which involved one half of the tank. Water samples containing the odors were introduced into the aquarium by means of a separatory funnel, which was connected to the siphon tube just after it left the tank. Two glass tubes, 2 by 24 inches in size, were filled with activated charcoal and connected in the circulation system of each tank. The water could be made to flow through them, during the interval between tests, without altering the rate of flow of the circulation. This treatment insured the complete removal of the test odors before the beginning of the next test and thus avoided olfactory fatigue of the fishes. It was found that trained fish no longer responded to an odor after it had passed through the filter.

Two carbon electrodes about 2 inches apart were located in each end of the aquarium. The space between them was designated as the "end zone," i.e., the place where the fish were fed or punished depend-

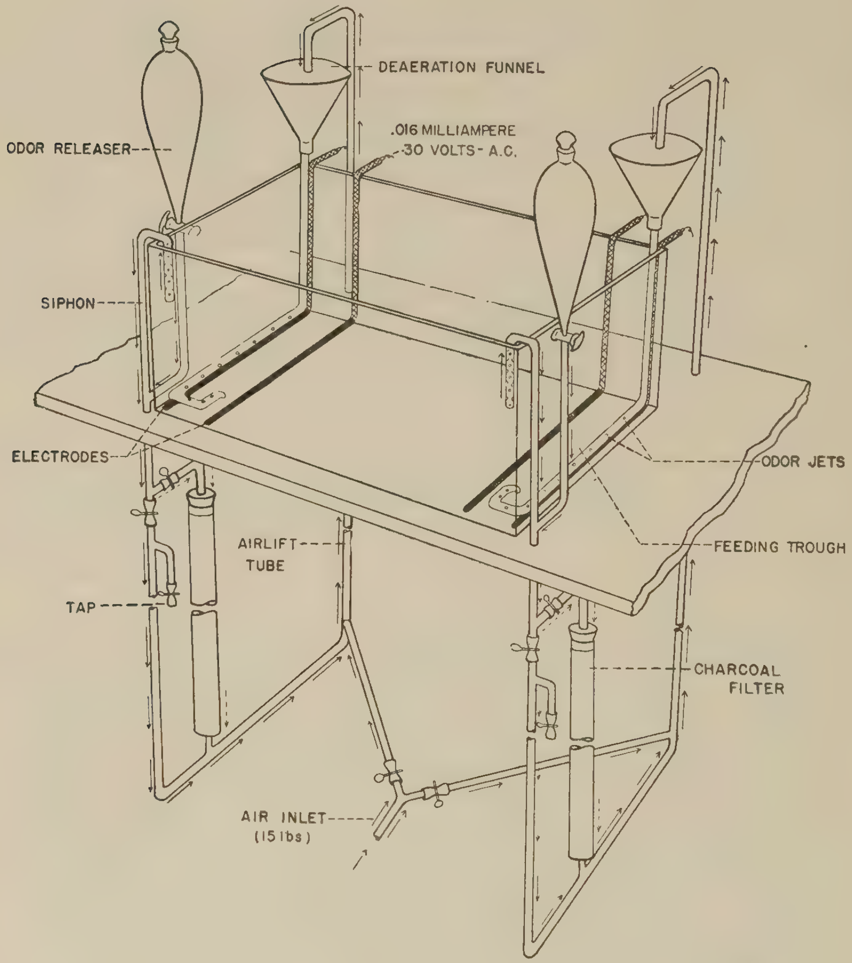
DEAERATION FUNNEL
.016 MILLIAMPERE
30 VOLTS - A.C.
ODOR RELEASER
SIPHON
ELECTRODES
ODOR JETS
FEEDING TROUGH
AIRLIFT TUBE
TAP
CHARCOAL FILTER
AIR INLET (15 lbs)

Figure 1.—Experimental tank with siphon-airlift circulation system.

ing on which odor was being introduced. By means of a switchboard, the operator could place 1.5 volts with 11.5 milliamperes current across the electrodes at either end of the aquarium. The fish were rewarded by introducing food pressed on perforated celluloid strips into the end zone.

With a set of electrodes and a jet in each end of the aquarium, it was possible to train from either end when the order in which the scents were presented was randomized. In order to eliminate cueing to the operator, the fish were blinded by chemical cautery (injection of phemerol into the posterior chamber of the eye). To remove any extraneous stimuli that the fish might receive during training the following precautions were taken: the aquaria were insulated from gross mechanical shocks by mounting them on sponge-rubber; introduction of the odor was accomplished in a manner that did not alter the dimensions of the stream of water which was constantly flowing into the aquarium; and the observer whispered scores to the recorder over a telephone system to avoid any association with change in pitch or rapidity of the observer's speech.

RESPONSE OF FISH TO TEST ODORS

The odor solutions used contained 0.002 p.p.m. of the phenolic compounds. These solutions were diluted with water from the aquarium so that the concentration of odor issuing from the jets was approximately 0.0005 p.p.m. No attempt was made to ascertain the concentration at which the fish detected the odor since this level varied with the position or location of the individual fish within the aquarium. If the water which issued from the jets was thoroughly mixed with the water volume in the aquarium, the concentration of phenolic compounds would be approximately 0.00002 p.p.m.

Fishes of two aquaria were trained to react positively to phenol by reward with food and negatively to p-chlorophenol by punishment with electric shock. Fishes in two other aquaria were trained to the same two odors, but with p-chlorophenol as the positive odor and phenol as the negative odor. If training was successful the fish should eventually associate food with the positive scent, and punishment with the negative scent.

The reaction of the fishes to the odors was tabulated on punch cards in accordance with the following procedure. Each fish was distinctively marked with a glass bead fastened to the back by a tantalum wire so that the results could be individually recorded. The score of the reactions for the entire aquarium was secured from the mean scores of the six fishes.

Scores were obtained for three different measurements of reaction as follows: (1) *test period* — scores were recorded during a 60-second test period coinciding with exposure to the odor. The test period was divided into intervals of 5 seconds and a fish scored five points if it entered the end zone one or more times during an interval; (2) *hesitation period*—five points were scored for each 5-second interval or part thereof which intervened between the time the fish perceived the odor and entered the end zone. This period was clearly defined because perception of the odor was manifested by a sudden change in behavior of the fish; (3) *pretest period*—during a pretest period of 60 seconds random movement was recorded by giving fish five points for one or more entrances into the end zone during each 5-second interval.

Positive and negative tests were given daily and it soon became evident that the fish had a natural dislike for the odors used. In order to overcome this difficulty positive tests alone were given for the first 2 weeks. At the end of this preliminary period the fish reacted to the positive odor without "fears." From then on, they continued to be fed immediately following the introduction of the positive odor, but were punished if they entered the end zone on the negative odor. Data collected after the preliminary period revealed that initially there were more entries on positive than on negative tests. Positive entries, however, decreased in number and discrimination learning began anew.

TABLE 1.—*Mean scores for trained fishes reacting to odor stimuli of phenolic compounds for a total of six tests where the positive odor was p-chlorophenol and the negative odor was phenol.*

Period of Training (months)	Odor	Tank number					
		4			5		
		Pretest period	Test period	Hesitation period	Pretest period	Test period	Hesitation period
1	Positive Negative	72 74	101 79	38 42	61 60	91 83	42 50
2	Positive Negative	68 67	145 25	19 104	57 46	188 26	12 113
4	Positive Negative	52 51	241 23	10 184	41 38	217 19	9 186

TABLE 2.—*Mean scores for trained fishes reacting to odor stimuli of phenolic compounds for a total of six tests where the positive odor was phenol and the negative odor was p-chlorophenol.*

Period of Training (months)	Odor	Tank number					
		9			10		
		Pretest period	Test period	Hesitation period	Pretest period	Test period	Hesitation period
1	Positive Negative	58 57	99 80	45 49	63 62	96 48	40 55
2	Positive Negative	56 57	201 30	7 143	59 53	164 29	16 99
4	Positive Negative	42 38	243 17	3 194	38 33	218 22	5 183

It is evident that the minnows learned equally well irrespective of whether phenol was positive (Table 1) or negative (Table 2). Moreover, they discriminated between the odors of phenol and p-chlorophenol at least 2 months after training began. Preliminary tests indicated that discrimination could have been accomplished faster had the fish been given slightly higher concentrations of the odorous compounds.

After fish have been trained to positive and negative odors, it is possible to introduce a third odor and thereby determine whether the fish associate it with the training odors. It is particularly informative if the unknown has any similarity to the negative odor. Such a generalization test was conducted, using o-chlorophenol as the third odor. Positive, negative and generalization tests were given daily in a randomized order and the fishes' scores recorded. The minnows did not clearly associate o-chlorophenol with either the positive or negative odors (Tables 3 and 4), although they did react as though it were more negative than positive. This condition may be caused by the fact that electrical shock is a stronger motivating force than hunger and that the odors were naturally offensive to the fish.

At the start of the experiments the fish were nervous and made high pretest scores. As the work progressed, these scores became lower, presumably because the minnows were better adjusted to the experimental conditions. Ablation of the nasal capsule of trained fishes by heat cautery eliminated their response to the test substances. It has been assumed, therefore, that the fishes detected the test compounds through the olfactory sense.

TABLE 3.—*Mean scores for trained fishes in tank 5 reacting to odor stimuli of phenolic compounds for a total of six tests where the positive odor was p-chlorophenol, the negative odor was phenol, and generalization (association) odor was o-chlorophenol.*

Odor	Pretest period	Test period	Hesitation period
Positive (p-chlorophenol)	35	272	3
Negative (phenol)	19	16	253
Generalization (o-chlorophenol)	26	90	122

TABLE 4.—*Mean scores for trained fishes in tank 10 reacting to odor stimuli of phenolic compounds for a total of six tests where the positive odor was phenol, the negative odor was p-chlorophenol, and generalization (association) odor was o-chlorophenol.*

Odor	Pretest period	Test period	Hesitation period
Positive (phenol)	27	248	4
Negative (p-chlorophenol)	29	18	254
Generalization (o-chlorophenol)	33	50	166

LIMITATIONS AND POSSIBLE APPLICATION

The biological assay of phenolic compounds by the method outlined in this work is primarily one of detection and not of quantitative analysis. Nevertheless, it demonstrated that these fish perceived phenolic compounds in concentrations as low as 0.0005 p.p.m. Since the lowest test concentrations lay below the threshold for man (0.01 p.p.m) no attempt was made to establish a threshold value by use of greater dilutions. Neurath (1949) compared the olfactory threshold of fishes and man and found that the minnow *(Phoxinus laevis)* was 250 times more sensitive to the odor of phenylethyl-alcohol.

Because the health of the experimental organism in biological assays is of primary importance, this method requires an operator who can maintain a colony of fish in good health. Moreover, continuous observation by the same operator assures precision.

In practice, fish should be trained negatively to the pollutant in one set of aquaria, and positively in another. If there were any trace of the pollutant present in an unknown water sample, the trained fish in the former group would react negatively, while a positive reaction in the latter group could possibly be interpreted as being induced by attractants other than the positive odor. Reverse training to the odor pair is a prerequisite to proper experimental procedure in this type of test.

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THE EFFECT OF LAMPREY ATTACKS UPON LAKE TROUT IN SENECA LAKE, NEW YORK

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Abstract

During an investigation of the spawning habits of the lake trout in Seneca Lake, New York, in October, 1941, it was obvious that an abundant population of sea lampreys was attacking the lake trout. It seemed probable that the attacked fish would be affected by loss of weight. Length-weight data and counts of all lamprey scars were obtained on a group of 65 ripe male lake trout and similar data with counts of only unhealed lamprey sores on another group of 66 ripe males. It was discovered that these lake trout suffered up to 10 successful lamprey attacks on one individual and possessed up to 4 unhealed sores while showing no indication that they were thinner as a result. The data showed that the larger lake trout suffered more attacks and were more vulnerable to attack. In addition, the data suggest that the lake trout in the samples acquired about two lamprey marks per year commencing at the age of 5 years and that they were somewhat more vulnerable to attack when spawning.

Introduction

Everyone who has caught a fish carrying the ugly red sore caused by the rasping mouth of a lamprey probably has speculated on the effect of such attacks on the future of his fishing. Under the belief that such an attack must injure the fish permanently, it is natural to blame the disappearance of game and food species on lampreys if they are abundant enough to attack many fish.

The sea lamprey *(Petromyzon marinus)* migrates from the sea to fresh-water streams for spawning. In the many lakes where it has become landlocked (some investigators think since post-glacial periods) it is usually known as the lake lamprey. The landlocked form is the one injurious to fresh-water fish (Gage, 1928), since the anadromous form comes to fresh water only for spawning and does not feed at that time. Because there is a widespread belief that lampreys are responsible for the disappearance of fish, it seems worth while to report the effect of sea lampreys on lake trout *(Cristivomer namaycush)* in a lake where both have existed in good numbers for many years and apparently are in reasonable equilibrium.

Many anglers think that the best fishing for lake trout in New York is in Seneca Lake, which supports a large population of rapidly growing lake trout. However, this lake with an area of 68 square miles and a maximum depth of 618 feet also supports a large population of sea lampreys. Gage (1928) wrote that he found sea (lake) lampreys in Seneca Lake in 1894, and in some years it was possible to pick up about 500 in only 2 hours during their spawning migration in a tributary stream.

The relative abundance of lake trout and sea lampreys in this lake may be judged from the incidence of attack. Gage (1928) noted that 34 out of 38 (90 percent) lake trout captured in Seneca Lake in 1927 bore lamprey scars. The present data (Table 1) indicate that 57 out of 65 (88 percent) mature male lake trout had been attacked, most of them more than once. In fact the 65 trout averaged 2.8 scars each.

TABLE 1.—*The total length (inches) and weight (pounds) of mature male lake trout captured in Seneca Lake, New York, October 1941, arranged according to the number of sea lamprey scars (healed and unhealed).*

Item	Number of lamprey scars						Totals
	0	1	2	3	4	5–10	
Number of fish	8	12	12	16	7	10	65
Mean length[1]	24.7	25.6	27.4	28.0	30.1	30.1	27.6
Range of lengths	22.6–27.8	22.4–31.7	24.0–30.5	23.8–31.9	27.8–33.3	28.0–32.9	22.4-33.3
Mean weight[1]	4.76	5.39	6.38	6.93	8.34	8.25	6.52
Range of weights	3.6–5.8	3.8–10.9	3.8–9.2	4.0–10.4	6.9–10.9	6.6–10.0	3.6–10.9
Estimated weight at 27.3 inches	5.93	6.45	6.21	6.32	6.18	6.51	6.24

[1] Means are geometric means taken from the calculations for the analysis of covariance.

The opportunity to collect data on the effect of lamprey attacks on lake trout occurred during an investigation of the life history of the lake trout in New York. In early October 1941, the State Conservation Department was gill-netting large numbers of lake trout near Peach Orchard Point in Seneca Lake for spawn-taking. It was obvious that sea lampreys were numerous in the lake. The fish were scarred and over 100 lampreys, ranging from 14 to 18 inches in length, were captured still attached to the trout. In cooperation with the Conservation Department, records of the total length, weight, and number of lamprey marks for each lake trout captured were obtained.

EFFECT OF LAMPREY ATTACKS

Since the lamprey attaches itself to a fish, rasps an opening through the skin, drinks its fill of blood, and then releases its hold leaving a large wound, it is reasonable to assume that a trout which has been attacked will be thinner than the average unattacked fish. In order to test this hypothesis, the length-weight relationship was computed for groups of the lake trout which were found with different numbers of lamprey marks. Only male lake trout were considered, because they were much more numerous in the catches and it was thought desirable to avoid sexual differences in length-weight relationship. Data on whether these males were ripe or spent were not recorded, but they were mostly ripe, because spent males were seldom caught. The original data were transformed to common logarithms in order to avoid the effects of curvilinear regression. A regression line was fitted to the transformed data for each group, and from each regression the weight at a length of 27.3 inches[1] (Table 1) was computed. These computed weights for the six groups varied from 5.93 to 6.51 pounds, but there appears to be little, if any, relation to the number of lamprey marks.

A critical test to determine the significance of this difference in the mean weight (adjusted for differences in length) according to the number of lamprey marks may be made by the analysis of covariance (Table 2). Such an analysis has been made by the procedure outlined in Snedecor (1946). In this analysis it is possible to obtain a variance attributable to the number of lamprey attacks and another to sampling variation. The *F*-test was used to compare these two sources of variation (mean square) and, in this analysis, to test the hypothesis that the differences in the mean adjusted weight of lake trout between the groups with different numbers of lamprey marks is not greater than would be expected from sampling variation. The very small *F* value (0.53) indicated that this hypothesis was true. No demonstrable difference existed among the mean weights of the various groups of this sample which had differing numbers of lamprey scars.

TABLE 2.—*The analysis of covariance showing the test of significance for the difference among the adjusted mean weights of lake trout with different numbers of lamprey marks of all kinds.*

Source of variation	DF	Sx^2	Sxy	Sy^2	Sum of squares	DF	Mean Square
Total	64	0.120545	0.348029	1.102966	0.098328	63	....
Marks	5	0.051734	0.148169	0.428210	....	..	....
Sampling	59	0.068811	0.199860	0.674756	0.094267	58	0.001528
Difference for test of significance					0.004061	5	0.000812

$$F = \frac{0.000812}{0.001528} = 0.53 \text{ (not significant)}$$

The possibility was considered also that the total number of scars, both healed and unhealed, might not provide a satisfactory basis for estimating the effects of attacks by the sea lamprey. Thus, if the ill effects were immediate, a more critical test could be made by classifying the lake trout according to the number of fresh, unhealed marks only. Since fresh and healed scars were not recorded separately on the first group of lake trout, a second set of data was collected in which only the unhealed sores were counted (Table 3).

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[1] Original measurements were made to the nearest half centimeter. Calculations were made from the metric data.

TABLE 3.—*The total length (inches) and weight (pounds) of mature male lake trout captured in Seneca Lake, New York in October 1941, and arranged according to the number of lamprey scars (unhealed only).*

Item	Number of lamprey scars				Totals
	0	1	2	3-4	
Number of fish	27	17	16	6	66
Mean length[1]	25.7	25.9	27.5	29.5	26.5
Range of lengths	22.8-32.5	22.6-29.7	24.0-32.1	26.4-32.9	22.6-32.9
Mean weight[1]	5.56	5.67	6.64	7.75	6.01
Range of weights	3.5-10.6	3.8-8.3	4.6-10.2	6.3-11.5	3.5-11.5
Estimated weight at 27.3 inches	6.47	6.31	6.44	6.22	6.40

[1] Means are geometric means taken from the calculations for the analysis of covariance.

Computation of the estimated weight at a length of 27.3 inches from these data shows a maximum difference of only 0.25 pound in the average weight, and a test of significance by the analysis of covariance (F was only 0.163) shows again that the differences in the mean weights are not associated with the number of unhealed lamprey wounds.

These two tests, which fail to show any correlation between the incidence of lamprey attack and the mean weight adjusted for length, are surprising when one considers that Schuck (1942) using an identical method of analysis, found a highly significant difference in the adjusted mean weight of two groups of brown trout *(Salmo trutta)*, one group of which had been tagged with jaw tags for a period of from 1 to 2 years. The tagged trout were significantly thinner than the normal, untagged trout.

SIZE OF TROUT AND INCIDENCE SCARS

When the lake trout are tabulated according to the total number of lamprey marks (Table 1) there is an increase in mean length associated with an increased number of lamprey marks. Lake trout without marks averaged 24.8 inches, and the length increased gradually to 30.1 inches for those with four lamprey marks. This increase represents an average of 1.3 inches per lamprey mark. An analysis of variance indicates that these differences in the mean length are much larger than would be expected from chance variation ($F = 8.87$).

Data on the ages of lake trout from Seneca Lake (unpublished) indicate that most of the spawning males captured in this manner were 5 or 6 years old, although younger and older fish were found in smaller numbers. Those with 5 annuli averaged 25.4 inches in length and those with 6 averaged 28.3 inches. If we assume from this fact that the mature male lake trout were growing about 2.9 inches per year and were acquiring one lamprey mark per 1.3 inches increase in length, it may be estimated roughly that the lake trout in this sample, on the average, acquired about two lamprey marks per year commencing at the age of 5 years.

A similar examination of the average length of lake trout classified according to the number of unhealed lamprey marks (Table 3) indicates a tendency for the larger lake trout in this sample to have a greater number of unhealed marks. An analysis of variance also indicated that the differences are much greater than would be expected from chance variation ($F=5.24$). If it is assumed that the lamprey marks heal in a few weeks (Gage, 1928, found that lampreys remained attached only a few days) then the larger lake trout in this sample were more vulnerable to attack.

When the incidence of recent and old attacks is compared it is found that the lake trout (Table 1) averaged 2.8 total lamprey marks per fish and (in another group of fish) 1.0 unhealed sores (Table 3). If we assume again that a sore remains unhealed only 1 month, then it appears that these lake trout possessed more unhealed sores in proportion to healed scars than would be expected from a random distribution of incidence of attack throughout the year. A random distribution of two attacks each year should cause about one-sixth of the marks to be unhealed rather than more than one-third. Possibly the concentration of spawning lake trout attracts lampreys and the spawning urge makes a fish take less notice of attacks.

CONCLUSIONS

The use of data from these samples to draw conclusions about the population in Seneca Lake is difficult. First, the sample consisted of mature males caught on the spawning migration by a gill net of uniform mesh size. Thus, it was not representative of the sexes or even of the complete size range of the mature males. Secondly, the lake trout which are included represent only those which have survived lamprey attacks, and the data provide no information on those which may have died. Furthermore, data on the relationship of sea lampreys and lake trout in Seneca Lake should not be applied to other lakes. Such factors as relative size of indivdual lampreys and trout, period of lamprey infestation in the lake, and presence of buffer species, may be different and important.

It is true, nevertheless, that the lake trout in Seneca Lake can survive numerous attacks—up to four at about the same time. It is a further fact that despite the presence of lampreys for more than 50 years, Seneca Lake provides good angling for lake trout. And, if lamprey attacks are often fatal, it is strange indeed that lake trout should show no indication of thinness after repeated attacks, even in such a restricted sample.

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RESULTS FROM PLANTINGS OF MARKED FINGERLING BROOK TROUT (*Salvelinus f. fontinalis* Mitchill) IN HUNT CREEK, MONTMORENCY COUNTY, MICHIGAN[1]

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Abstract

Fin-clipped fingerling brook trout (*Salvelinus f. fontinalis* Mitchill) both hatchery-reared and wild, were released in Hunt Creek in late summer or fall of 1939 and 1940. Their contribution to the catch in subsequent years was determined by creel census and anglers' reports. The extensive experiments involved release of 35,109 and 17,635 marked fingerlings, respectively, throughout the length of Hunt Creek. Marked fish entered the anglers' catches in 1941 and 1942, and made up from 0.27 to 2.56 percent of the observed catch of legal brook trout in various years. The total known percentages of recovery were 0.07 percent (26 fish) of the 1939 release, and 0.28 percent (49 fish) of the 1940 planting.

Intensive experiments with both wild and hatchery-reared brook trout fingerlings marked by different fin combinations were carried on simultaneously in Section C of the experimental waters of Hunt Creek. Marked hatchery-reared fingerlings released in 1939 contributed from 0.0 to 0.26 percent of the total observed catches of legal brook trout in later years; 1940-marked hatchery fingerlings made up from 0.00 to 0.45 percent of total observed catches in later years. Wild fingerlings marked at the same time made up from 0.00 to 1.80 percent of catches recorded in subsequent seasons. Larger percentages of recovery were noted for the smaller of the two releases (1940).

Through the use of the formula $M = \frac{1{,}000\,A}{BC}$ where M = migration or abundance index from a release locality to a recovery locality, A = number of marked fish recovered in a given locality, B = number of fishing units of effort in a given locality, and C = total number of marked fish released in a given locality, it was demonstrated that the majority of wild and hatchery-reared marked fingerlings in the intensive experiment stayed within the limits of the experimental sections, although they did move out of Section C, except for the hatchery-reared fingerlings recovered in 1942, which were farther downstream than usual.

General growth data on marked fingerlings of both types indicated that probably those fish which were largest at the time of marking and release came into the legal catch first.

It was concluded that brook trout fingerling planting is a wasteful procedure because a low percentage reaches the anglers' creels. Creel census data demonstrate that despite the elimination of fingerling stocking in Hunt Creek following 1940, angling quality has not deteriorated.

Introduction

Results of previous experimental plantings of marked fingerling trout reported by the author (Shetter, 1939) and others (Surber, 1937, 1940;

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[1] Contribution from the Michigan Institute for Fisheries Research.

Needham and Cliff, 1938; Chamberlain, 1943; Holloway and Chamberlain, 1942; and Needham and Slater, 1944) indicate that a very small percentage of trout which are released in streams as fingerlings (2-5 inches total length) ever reach anglers' creels as legal fish. The data presented hereafter give additional support to this general conclusion.

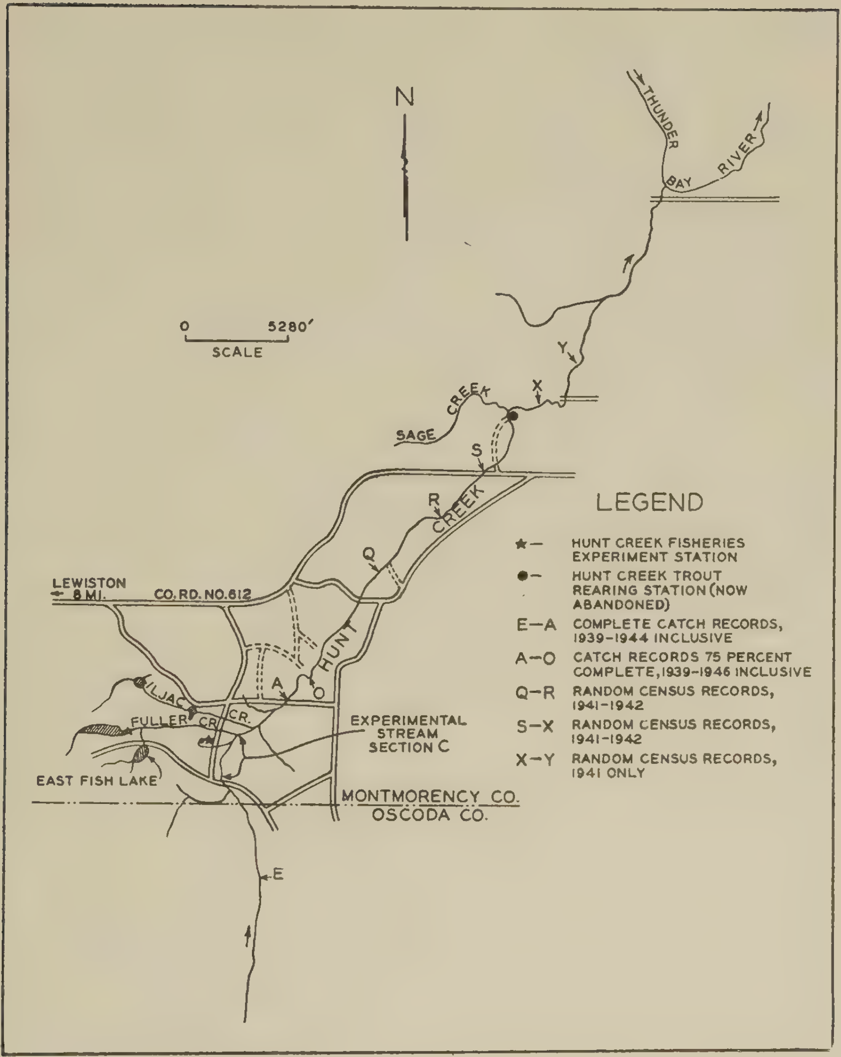
With the establishment of the Hunt Creek Fisheries Experiment Station in 1939, plantings of fin-clipped brook trout fingerlings of both wild and hatchery origin were made in a section of the experimental stream, and releases of fin-clipped hatchery-reared brook trout fingerlings only were also made throughout the Hunt Creek system. These marked plantings were followed by creel census in order to record the numbers and kinds of marked and unmarked fish which entered the catch in subsequent years.

Description of the Stream

Hunt Creek, one of the shorter tributaries of the Thunder Bay River, is located in the northeastern portion of the Lower Peninsula of Michigan in south-central Montmorency County. Approximately 12 miles long, it flows in a northeasterly direction between rolling, wooded hills of moderate height. Cedar-spruce-tamarack swamps border much of its length in the upper reaches; elsewhere there are scattered meadow stretches which were formed by beaver activity or by old logging dams. As one progresses downstream the channel winds through groves of aspen mixed with conifers and a few hardwoods and allied shrubs. Along the stream border proper there is an abundance of tag alder.

The stream bottom consists chiefly of small rubble and gravel of several degrees of fineness mixed with varying proportions of sand and silt. Some clay can be observed in the lower stretches. The stream varies in width from about 5 feet in the headwaters to about 40 feet in the widest portions toward the mouth, with an average between 20 and 30 feet. Maximum depth ranges from 3 to 4 inches on some of the shallow riffles to 5 or 6 feet in a few of the deeper pools. However, most of the pools are between 2 and 4 feet deep. The current velocity varies from 0.5 to 2.5 feet per second. In the lumbering days, Hunt Creek was reported to be one of the faster streams of the Thunder Bay River drainage on which timber was driven, and the remains of four old logging dams are still evident. Along most of its length, the stream is fed by springs which keep the water temperature below 70° F., except during the hottest part of the summer when the lower reaches may become somewhat warmer.

The brook trout is the only species of trout permanently established in Hunt Creek. A few rainbow trout *(Salmo gairdnerii)* are captured by anglers in the lower stretches each year, but apparently do not reproduce in the stream. Observations during the 1943 and 1944 spawning seasons indicated that brook trout reproduction took place throughout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FULLER CR.
CR.
EAST FISH LAKE
EXPERIMENTAL STREAM SECTION C
MONTMORENCY CO.
OSCODA CO.
LEGEND
★— HUNT CREEK FISHERIES EXPERIMENT STATION
●— HUNT CREEK TROUT REARING STATION (NOW ABANDONED)
E—A COMPLETE CATCH RECORDS, 1939–1944 INCLUSIVE
A—O CATCH RECORDS 75 PERCENT COMPLETE, 1939–1946 INCLUSIVE
Q—R RANDOM CENSUS RECORDS, 1941–1942
S—X RANDOM CENSUS RECORDS, 1941–1942
X—Y RANDOM CENSUS RECORDS, 1941 ONLY

FIGURE 1. Map of Hunt Creek drainage showing major tributaries and road crossing.

the entire system, but that the upper half of the stream was most used for this purpose.

A sketch map (Figure 1) shows the location of the major tributaries, and the nature of the creel census operated on different portions of Hunt Creek in the various years.

METHODS

Hatchery-reared fingerling brook trout were supplied from a state-owned rearing station located about 5 miles downstream from the experimental area (Figure 1) and marking operations on the artificially-reared fish were conducted there. Wild brook trout fingerlings were obtained for marking by seining in Section C, and were measured, marked, and counted as the predetermined numbers were collected within that section. Brook trout fingerlings were fin-clipped for future identification by using a different fin or fin combination for each year and for each type of fish (wild or hatchery-reared). Curved-blade manicure shears were employed to remove the fins flush with the body surface. Regeneration of clipped fins has been negligible, probably never so much that marked fish could not be recognized as such by creel census clerks or observant anglers. Shetter (1939) found a difference in mortality of dorsal and adipose fin-clipped brook trout fingerlings over unmarked controls (both lots held in hatchery ponds) of 8.6 percent at the end of 2 years after marking. There was no significant difference in growth and although some regenerations of the rayed dorsal fin occurred in a few individuals there was no regeneration of the adipose fin, and all the marked fish could be identified readily after 2 years.

Creel census operations varied on different portions of the Hunt Creek drainage. In all years, catch records from the section E-A (Figure 1) have been from 97 to 100 percent complete, and catch records from the section A-O are estimated to be 75 percent complete for all years. In the years 1941 and 1942, random records were available from sections Q-R and S-X; random census records are available for the section X-Y for 1941 only. In certain years a few additional records were obtained from stream areas other than those indicated, and have been used also in arriving at season totals. The records for Fuller Creek and East Fish Lake outlet are believed to be complete.

When intensive creel census operations were inaugurated in 1939 on the experimental waters of Hunt Creek, four sections of stream, all quite different in character, were designated Sections A, B, C, and D for the purpose of recording the angling results in the different types of brook-trout water. Section E was added and checked during 1940 and thereafter. The downstream terminus of Section A is at A (Figure 1) and Section E has its upstream boundary at E. The other sections lie in alphabetical order between them, and vary in length from 1,250 feet (Section E) to 3,970 feet (Section C).

In making up season totals for the Hunt Creek angling, use has been made of all available records which represented fishing effort on any portion of the drainage to which the marked fish might have moved. The total numbers of marked fish recovered have been listed also.

Marked hatchery fish from the extensive experiments were not included in the total catch when considering results obtained from the intensive experiments, and vice versa. Tagged hatchery fish entering the catch of 1941 from the spring planting of legal-sized fish in that year likewise were not included in the totals for 1941.

Two experiments were operating simultaneously. One, termed "extensive," involved hatchery-reared fingerlings only, planted in large numbers over the entire stream system mostly outside of the experimental area. The smaller, "intensive" experiment involved the use of similar numbers of both wild and hatchery-reared fingerlings of approximately the same size and age, in the same stream area. It was hoped that the complete creel census data available for the stream section E-A could be utilized to determine the results of the intensive experiment. However, recoveries of marked fingerlings from the intensive experiment outside the area covered by complete census invalidated the use of only the catch figures for the stream section A-E. Instead, it seems more correct to use all available catch data for the entire stream in interpreting the results of both experiments.

EXTENSIVE EXPERIMENTS

When research operations were begun on Hunt Creek in 1939, it became desirable to know whether or not the fish which came into the catch in later years were of natural or artificial origin. The stream had been stocked heavily for a number of years preceding 1939, although Hunt Creek was known to produce a plentiful supply of fingerlings each year from natural spawning. To permit accurate determination of which fish in the legal catch of the experimental waters and elsewhere were originating from hatchery-reared fingerlings, the entire plantings of brook trout of this size in 1939 and 1940 were fin-clipped before release. No hatchery-reared fingerlings have been released in the area since 1940. Two thousand legal brook trout, all jaw-tagged, were planted in March, 1941, in the stream below the experimental area. All plantings of legal trout in East Fish Lake in 1940, 1941, and 1942 were marked by either jaw-tag or distinctive fin clip combination. After September, 1941, trout in East Fish Lake were confined to the lake by a fish-tight weir.

The 1939 planting consisted of 35,109 brook trout ranging in size from 2.2 to 4.8 inches (average 3.3 inches, based on a random sample of 114 specimens). This number was approximately the same as the usual annual planting of fingerlings made in the stream system each year prior to 1939. These fish, marked by clipping the dorsal and adipose fins, were scattered over the length of Hunt Creek at various locations outside the experimental area, except for about 1,200 fish which were planted by error within the confines of the experimental sections. The marking and planting were conducted during the period September 27-October 4, 1939.

In 1940, a similar procedure was followed, except that only 17,635 brook trout fingerlings were used (approximately one-half of the 1939 release), and the fish were marked by clipping the adipose and right pelvic fins. These were marked and released in Hunt Creek outside of the experimental sections between September 19 and 23, 1940. The size range of the 1940 release was 2.5 to 4.5 inches (average 3.2 inches based on a random sample of 200 specimens).

The length of the stream, the road pattern (which provides numerous points of access), and the number of private cabins combine to make an intensive type of creel census over the entire stream impracticable. Data on the fishing in the years following these plantings were obtained on the lower portions of Hunt Creek outside the experimental area through random census of short portions of the stream, and by reports from interested anglers. Explanatory signs were placed at cabins, bridges, and parking sites requesting reports of fishing success, number of marked and unmarked fish in the catches, etc. From the data secured, it is impossible to estimate the total catch for the stream for any year, or the total percentage of recovery of marked fish, but the percentage of the observed catch contributed by plantings of hatchery-reared fish in 1939 and 1940 can be determined. Data on angling, including the number of marked hatchery-bred fish captured, are listed in Table 1.

No marked fish from the extensive planting of 1939 were observed in the legal catch by Institute personnel in the 1940 trout season, despite the previously-mentioned release of approximately 1,200 marked fish within the experimental waters. The caretaker of the Hunt Creek Rearing Station during the summer of 1940 asserted that "quite a few" legal fish with the dorsal-adipose mark were taken in that year in the vicinity of the rearing station, but could give no estimate of the catch of either marked or unmarked fish

In 1941, out of 1,251 brook trout examined in fishermen's catches 23 dorsal-adipose marks (1939 planting), and 32 right pelvic-adipose marks (1940 release) were observed. These hatchery fish constituted 1.84 and 2.56 percent, respectively, of the total observed legal catch of 1941.

In 1942, from a total of 1,126 legal brook trout examined, there were noted 3 dorsal-adipose marks and 17 right pelvic-adipose marks, or 0.27 and 1.51 percent, respectively, of the observed catch of 1942. No marked fish from either planting were reported in the 1943, 1944, 1945, or 1946 seasons, nor were they observed in any of the catches examined in those years (1943—630 legal fish; 1944—756 legal fish; 1945—585 legal fish; 1946—811 legal fish).

The total known percentage of recovery on the extensive plantings of large numbers of fingerling brook trout is as follows: 1939 planting, 26 out of 35,109 fingerlings recovered by anglers as legal fish, or 0.07 percent; 1940 planting, 49 out of 17,635 fingerlings recovered as legal fish by anglers, or 0.28 percent. Even though one assumes that only one-tenth of the legal catch was observed, it will be noted that the per-

TABLE 1.—*Summary of all available angling data for Hunt Creek and tributaries for the seasons 1939-1946 inclusive, showing the numbers of marked fall-planted, hatchery-reared brook trout fingerlings of the "extensive" experiment entering the observed legal catch.*

Season	Total anglers interviewed	Total hours of angling	Total legal brook trout taken	Sub-legal brook trout returned	Catch per hour		Number of marked hatchery fish caught		Percentage of marked hatchery fish in catch	
					Legal	Sub-legal	1939 plant	1940 plant	1939 plant	1940 Plant
1939	642	1,242.50	730	5,488	0.59	4.42	....	....	....	....
1940	693	1,367.50	623	5,322	0.46	3.89	....	....	....	....
1941	1,681	2,974.25	1,251	10,499	0.42	3.53	23	32	1.84	2.56
1942	1,233	2,289.00	1,126	6,666	0.49	2.91	3	17	0.27	1.51
1943	443	990.25	630	4,282	0.64	4.37	0.00	0.00	0.00	0.00
1944	633	1,279.50	756	5,510	0.60	4.31	0.00	0.00	0.00	0.00
1945	658	1,237.75	585	5,796	0.47	4.68	0.00	0.00	0.00	0.00
1946	1,284	2,152.50	811	7,208	0.38	3.35	0.00	0.00	0.00	0.00
Totals, averages	7,267	13,533.25	6,512	50,771	0.48	3.75	26	49	0.45	0.95

centages of recovery would still be very low—0.70 percent for the 1939 planting, and 2.80 percent for the 1940 release.

It should be pointed out that the angling data available from all sources, both intensive and random, indicate that the quality of the fishing (as measured by the number of legal trout caught per hour of fishing) has not suffered since the cessation of stocking fingerling trout in the fall of 1940. If the creel census data for the 4 years during which it is known that hatchery fingerlings were present in the stream (1939, 1940, 1941, and 1942) is averaged, an average catch per hour of 0.47 legal trout for those years can be demonstrated. For the years when no marked hatchery-reared fingerlings were observed in the creel census, and also when they were not planted (1943, 1944, 1945, and 1946), the average catch per hour of legal trout was found to be 0.49 fish, or slightly better for the latter period.

Undersized brook trout increased noticeably during the 4-year period when no hatchery-reared fingerlings were present or planted, according to a comparison of the catch per hour of undersized fish for 1939-1942 (3.55) and 1943-1946 (4.03).

In view of the discontinuance of stocking, it must be concluded that the legal and sublegal fish reported in the last 4 years are the result of natural spawning and that the quality of fishing has not suffered from a policy of no stocking.

INTENSIVE EXPERIMENTS

Since the start of the 1939 trout season, approximately 2 miles of the headwaters of Hunt Creek have been under intensive creel census, a practice which has permitted examination of almost 100 percent of the total catch of the stream section A-E (Figure 1).

In August, 1939, Section C was seined throughout its length, and 1,000 fingerling brook trout, all presumably young-of-the-year resulting from the 1938 fall spawning, were marked by clipping the left pectoral fin and immediately returned to the water. These fingerlings ranged in total length from 1.9 to 3.8 inches (average 2.6). One thousand hatchery-reared brook trout fingerlings ranging in size from 1.7 to 4.8 inches (average 2.7) were obtained from the Hunt Creek Rearing Station and marked by clipping the right pectoral fin. They were scattered at random throughout the length of Section C at the rate of 1,320 fish per mile of stream, or 934 fish per acre of water (Table 2).

A similar procedure was followed in August, 1940, except that 500 wild brook trout fingerlings were marked and returned to Section C, and 464 hatchery fingerlings were fin-clipped and planted, the latter at the rate of 642 per mile of stream, or 433 per acre. The wild fish of 1940 were marked by removing the left pelvic fin, and the hatchery-reared fish by the excision of the right pelvic fin. Their sizes were as

TABLE 2.—*Summary of marking information concerning wild and hatchery-reared brook trout fingerlings in Section C, Hunt Creek, 1939 and 1940. Total lengths are given in inches, weights in ounces.*

Date released	Origin of fish	Mark used	Number marked	Average size		Range in total length
				Total length	Weight	
August 21-24, 1939	wild	left pectoral	1,000	2.60	0.09	1.93-3.78
August 25, 1939	hatchery	right pectoral	1,000	2.72	0.12	1.69-4.76
August 10, 1940	wild	left pelvic	500	2.64	0.11	1.97-3.35
August 12, 1940	hatchery	right pelvic	464	2.52	0.09	1.57-3.35

follows: hatchery fingerlings, range 1.6 to 3.3 inches (average 2.5); wild fingerlings, range 1.9 to 3.3 inches (average 2.6).

The recovery of fin-clipped fish as legal trout is summarized in Table 3. One recovery of a wild fingerling marked in 1939 appeared in the 1940 catch of the experimental waters, but during the 1941 season, the 1939 mark was most common. In the 1942 season the fingerlings marked in 1940 contributed more fish than the 1939 releases, while in 1943 and 1944, the few recoveries were about equally distributed between the two releases. It may be computed from creel census data that the hatchery-reared fingerlings have either failed to increase the total catch or have increased it by only an insignificant amount. The 1939 planting of 1,000 hand-reared fingerlings which later grew to legal size constituted 0.00 percent of the 1940 catch (no hatchery fish taken), 0.25 percent of the 1941 catch (3 fish), 0.00 percent of the 1942 and 1943 catches (no fish), and 0.26 percent of the 1944 catch (2 fish).

The 1940 planting of 464 hatchery-bred brook trout fingerlings made up the following percentages of the total catch in succeeding years: 1941—0.08 percent (1 fish); 1942—0.45 percent (5 fish); 1943 and 1944—0.00 percent (no fish from this planting in either year).

The total percentage of recovery in each category of marked fish up to the end of the 1944 season was as follows: from the 1,000 wild brook trout fingerlings clipped and released in August, 1939—2.60 percent; from the 1,000 marked hatchery fingerlings released at the same time—0.50 percent; from the August, 1940, marking of 500 wild brook trout fingerlings—5.00 percent; from the 464 hatchery fingerlings marked and planted in August, 1940—1.29 percent. Since the smaller plantings yielded percentages of recovery that were over twice or nearly twice as large as the larger plantings both for native and planted stock, the reduction in the rate of stocking by one-half apparently increased the survival rate. The reason for the increased survival rate, and in turn the increased percentage of recovery by anglers, probably lies in the fact that the smaller planting of hatchery-reared fingerlings resulted in considerably less competition for food and space between wild and hatchery-reared fingerlings and between the introduced fingerlings them-

TABLE 3.—*Number of marked hatchery-reared and wild brook trout fingerlings recovered from the markings and plantings in Section C, Hunt Creek, in 1939 and 1940, together with locality of recovery, and percentages of the total catch made up by the various plantings, and percentage of recovery for the period 1940-1946 inclusive. (W = wild, H = hatchery.)*

Item	1941 season				1942 season				1943 season				1944 season				Totals, all seasons[1]			
Recovery area	1939 planting		1940 planting		1939 planting		1940 planting		1939 planting		1940 planting		1939 planting		1940 planting		1939 planting		1940 planting	
	W	H	W	H	W	H	W	H	W	H	W	H	W	H	W	H	W	H	W	H
Section E	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Section D	7	3	1	1	6	0	13	1	0	0	0	0	0	0	0	0	13	3	14	2
Section C	3	0	0	0	4	0	4	0	1	0	2	0	0	0	1	0	8	0	7	0
Section B	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2	0	1	0
Section A	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	2	1	0
Below A	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1
Other	1	0	0	0	1	0	1	3	0	0	0	0	0	0	0	0	2	0	1	3
Total recoveries each year	12	3	1	1	11	0	21	5	2	0	2	0	0	2	1	0	26	5	25	6
Number available in year	999	1,000	500	464	987	997	499	463	976	997	478	458	974	997	476	458	1,000	1,000	500	464
Percentage of total observed catch made up by various markings	1.00	0.25	0.08	0.08	0.99	0.00	1.80	0.45	0.32	0.00	0.32	0.00	0.00	0.26	0.13	0.00	0.45	0.09	0.49	0.12
Cumulative percentage of recovery at end of each year	1.30	0.30	0.20	0.21	2.40	0.30	4.40	1.29	2.60	0.30	4.80	1.29	2.60	0.50	5.00	1.29	2.60	0.50	5.00	1.29
Total observed catch of legal trout in year	1,200				1,111				630				758				5,718		5,095	

[1] In 1940, one wild marked fish, taken in Section B, was observed among the total of 623 legal trout checked. In 1945, no marked trout were seen in the total of 585 legal trout observed; in 1946 no marked trout were among the total of 811 examined.

selves. Similar results were noted in the extensive experiment, where 26 of 35,109 hatchery fingerlings were reported as legal fish (0.07 percent recovery), while 49 of 17,635 fingerlings planted the following year were reported later as legal brook trout (0.28 percent recovery). Surber (1937) also found higher survival from smaller plantings when stocking rainbow trout fingerlings. In experiments involving the planting of various numbers of marked legal-sized trout, higher rates of survival to the angler have been noted by Shetter and Hazzard (1941) and Gee (1942) for smaller plantings than for larger plantings. These facts suggest that when more trout are released in a stream than can be supported by that body of water, survival rates for both the planted trout and the native trout are lowered.

No marked fish from these experiments entered the catches in 1945 and 1946. One left pectoral-marked brook trout was observed in the catch of Below Section A in 1944, and a right pectoral-marked fish of less than legal size (6.9 inches, total length) was removed from the same section in 1945. However, examination of the scales of these fish (by Dr. E. L. Cooper) demonstrated that they were not from the 1939 markings, as no more than three annuli were to be observed on the scales of either fish. It is believed that they had suffered natural injuries to these fins, or were fish from experimental markings in Sections A and C in which the dorsal plus either the right or left pectoral fins were removed, and on which the dorsal fin had regenerated.

Migration of the Fingerlings in Section C

Since the fishing effort (hours of angling) was known for the various localities in which the marked fish were recovered, it is possible to calculate an "abundance index" for the various localities; or the index figure so obtained may be regarded as indicating the amount of migration from Section C, where all of the marked fingerlings of the intensive experiment were liberated. Such treatment of the recovery data from the extensive experiments was not possible because marked fish were scattered at various localities along the length of Hunt Creek and the fishing effort was not known outside of the experimental area.

Other fisheries workers have realized that there is a relationship between fishing intensity and the number of marked fish recovered. Schroeder (1930) stated that the intensity of the cod fishery in the Nantucket shoals had a direct bearing on the proportion of marked cod in the catch, but his data were insufficient for the calculation of any abundance or migration indexes. Thompson and Herrington (1930) demonstrated a definite relationship between the actual number of tagged halibut recovered and the possible number that probably would be recovered by the intensity of the fishery on the halibut grounds off the southern coast of the Alaskan Peninsula. Although the results of calculations relating to brook trout migrations are expressed here in a manner differing from that employed by Thompson and Herrington, the basic factors considered have been the same, namely, the number of marked fish recovered, the number of marked fish available, and the number of units of fishing effort expended to effect recoveries in the various areas.

If the number of units of fishing effort in all areas was constant, the number of marked fish recovered in the various localities would furnish an accurate picture of the migratory tendencies of marked fish. However, angling pressure on different stream areas is seldom uniform, and the number of units of fishing effort must enter into the calculations. The proper interpretation of the factors listed above is of considerable importance, as may be illustrated by a hypothetical example. Suppose 100 marked fish are introduced into area T on a stream, and in their dispersion 70 move upstream into area U and 30 move downstream into area D. If there are 10 hours of fishing in area D, and only 1 hour of fishing in area U, the possibilities are much greater of recovering fish which have migrated downstream. Assume further that the aforementioned fishing in the two localities produced 20 recoveries in area D and 5 recoveries from area U. Judged only on the basis of comparative numbers of fish recovered, it would appear that there was a stronger tendency for the fish to move downstream than upstream whereas exactly the opposite was the case.

If the results just given were weighted by the available number of marked fish and the number of units of fishing effort used in each area, the true migration indexes from area T to areas U and D would be obtained. In determining this index the number of marked fish captured per unit of fishing effort in a given area is divided by the number of marked fish available from a given area of release, and the resulting figure multiplied by 1,000 for the sake of convenience. This procedure may be expressed by the formula:

$$M = 1000 \frac{A/B}{C} = \frac{1000\ A}{BC},$$

in which

M = migration (or abundance) index from any given area of release to any given area of recovery,
A = number of marked fish recovered in any given area,
B = number of units of fishing effort in any given area,
C = total number of marked fish released in any given area.

Substituting the hypothetical values in the formula we find the following results:

Migration index from area T to area U upstream

$$M = \frac{1000 \times 5}{1 \times 100} = \frac{5000}{100} = 50;$$

Migration index from area T to area D downstream

$$M = \frac{1000 \times 20}{10 \times 100} = \frac{20000}{1000} = 20.$$

TABLE 4.—*Migration indexes for marked wild and hatchery-reared brook trout fingerlings release in Section C in the falls of 1939 and 1940 and recovered in the 1940-1944 seasons. (W = wild; H = hatchery.)*

Stream section	1940		1941				1942				1943				1944			
	1939 planting		1939 planting		1940 planting		1939 planting		1940 planting		1939 planting		1940 planting		1939 planting		1940 planting	
	W	H	W	H	W	H	W	H	W	H	W	H	W	H	W	H	W	H
E	0.00[1]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.043	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D	0.00	0.00	0.011	0.005	0.004	0.004	0.012	0.00	0.047	0.004	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	0.00	0.00	0.007	0.00	0.00	0.00	0.010	0.00	0.020	0.00	0.008	0.00	0.031	0.00	0.00	0.00	0.013	0.00
B	0.116	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.016	0.00	0.014	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.010	0.00	0.00	0.00	0.00	0.00	0.00	0.013	0.00	0.00
Below A	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	0.00	0.00	0.001	0.00	0.00	0.00	0.003	0.00	0.005	0.016	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[1] Where index is 0.00 no trout were recovered even though section was fished. The greater the index figures, the greater the number of marked fish which were recovered.

In other words, instead of a greater tendency toward downstream movement, as conjectured from the recoveries alone, there is actually indicated an upstream migration 2.5 times as great as the downstream movement.

The recovery data from the fingerlings planted in or marked in Section C were analyzed by the method just described, and showed that there was some shift in the centers of abundance of the marked fish after release in Section C, among both the wild and the hatchery-reared fish (Table 4). Considering the indexes by trout seasons, the legal fish originating from the two plantings were dispersed as follows (center of greatest abundance given first, and those of lesser abundance following in order):

1940 season — 1939 wild fish — Section B, hatchery fish — not known.
1941 season — 1939 wild fish — Section D, Section C, Below A, Other, hatchery fish — Section D.
1940 wild fish — Section D, hatchery fish — Section D.
1942 season — 1939 wild fish — Section D, Section C, Other, hatchery fish — not known.
1940 wild fish — Section D, Section E, Section C, Section B, Other, hatchery fish— Other, Section D, Below A.
1943 season — 1939 wild fish — Section B, Section C, hatchery fish — not known.
1940 wild fish — Section C, hatchery fish — not known.
1944 season — 1939 wild fish — not known, hatchery fish — Section A.
1940 wild fish — Section C, hatchery fish — not known.

The majority of the 1939 (23 of 26) and 1940 (24 of 25) wild marked fingerlings appear to have stayed within the limits of the experimental sections, although most of them moved out of Section C before capture.

Of the five 1939 hatchery fingerlings taken as legal-sized fish, three were recovered in Section D in 1941, and two were recaptured in Section A in 1944. Hatchery fingerlings released in 1940 exhibited a greater tendency to move downstream after 1941. In 1942, four of the five recoveries from this planting were retaken at points downstream from the experimental sections. The apparent wandering noted for the smaller of these two releases has been puzzling. However, it appears (Table 4) that the majority of hatchery fingerlings were recovered as fish 7 inches or larger and less than a mile from the locality of release. The same was true for the wild fingerlings marked in Section C.

THE GROWTH OF THE MARKED FISH

Information of a general nature is available on the growth of the marked fish, since their size at recovery (Table 5) in the legal catch and their average size at the time of marking and release (Table 2) is known. As might be expected, the minimum size was very close to 7 inches, since that was the legal size limit set on the experimental stream at that point. The largest wild marked fish recovered from the 1939 planting was 9.9 inches; from the 1940 marking of wild fish, 9.0 inches.

The largest marked hatchery fish recovered were as follows: from the 1939 planting, 7.6 inches; from the 1940 planting, 7.6 inches.

It would appear that the faster-growing individuals or those which were larger at the time of marking came into the legal-size class and into the catch in earlier years. The individuals which became 7 inches long 3 or more years after release unquestionably were the more slow-growing individuals. There seemed to be little regularity in the increase in the average lengths probably because of the small number of recoveries. For almost any planting, the average increment based on the size at recovery might be less for one year than for the year preceding.

Table 5.—*Average size of marked fingerling brook trout planted or marked in Section C, Hunt Creek in August, 1939 and August, 1940, and recovered by angling in later years. (Total length expressed in inches; weights are given in ounces.)*

Year of recovery and item	Year of planting and source of fish			
	1939 wild	1939 hatchery	1940 wild	1940 hatchery
1940—Number recovered	1	....	....	....
Size range	8.6	....	....	....
Average total length	8.6	....	....	....
Average weight	3.2	....	....	....
Increase in average total length	6.0	....	....	....
1941—Number recovered	12	3	1	1
Size range	7.0–9.7	7.0–7.4	9.0	7.0
Average total length	7.5	7.2	9.0	7.0
Average weight	2.3	2.2	3.3	1.9
Increase in average total length	4.9	4.5	5.4	4.5
1942—Number recovered	11	....	21	5
Size range	7.0–8.1	....	6.9–8.6	7.0–7.6
Average total length	7.3	....	7.5	7.5
Average weight	2.2	....	2.3	2.2
Increase in average total length	4.7	....	4.9	5.0
1943—Number recovered	2	....	2	....
Size range	8.0–9.9	....	7.6–8.8	....
Average total length	8.9	....	8.3	....
Average weight	4.6	....	3.0	....
Increase in average total length	6.3	....	5.7	....
1944—Number recovered	....	2	1	....
Size range	....	7.1–7.6	7.2	....
Average total length	....	7.3	7.2	....
Average weight	....	2.0	2.2	....
Increase in average total length	....	4.6	4.6	....

CONCLUSIONS

Both the intensive and extensive experiment on Hunt Creek, and the research described for other parts of the continent, indicate that anglers may expect to recover as legal fish a comparatively small percentage of a planting of fingerling brook trout. Assuming that the creel census from the extensive experiment on Hunt Creek was only 10 percent efficient, one could expect a maximum recovery of only about 3 percent of fall-planted fingerling brook trout. Under conditions unfavorable to hatchery-reared fish this recovery would probably approach zero. The great majority of recoveries that survive to reach the angler's creel will be made in the first 2 years after release. On Hunt Creek, hatchery fingerlings from any one planting have never constituted more than 2.56 percent of the observed total catch in any one year, and the percentage declines rapidly to zero in following years. Since the elimination of hatchery planting of fingerling brook trout in Hunt Creek, creel census records furnish evidence that angling quality has been as good or slightly better than in those years hatchery fingerlings were present.

In view of the experimental evidence recorded in the literature and the facts discussed above, it must be concluded that the planting of fingerling brook trout in streams which produce numerous brook trout fry is an inefficient management procedure. In all probability any such hatchery fingerlings which arrive at the legal size of 7 inches do so at the expense of an equal number of naturally-reared brook trout. It would appear that emphasis in trout management should be placed upon increasing the natural carrying-capacity of the habitat, rather than upon trying to force the habitat to support two legal brook trout where there is space and food for only one. Since the productive capacities of trout waters are definitely limited, lower creel limits will also aid in spreading the available supply among more anglers.

The only instances where fingerling plantings of brook trout in streams might appear to be justified are: (1) where angling pressure has been so heavy that insufficient brood stock is left; (2) where the breeders of a stream system have been removed by some natural catastrophe; and (3) where suitable spawning conditions do not exist and cannot be created at a reasonable cost.

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SOME TESTS WITH EXPERIMENTAL GROUPS OF FINGERLING RAINBOW TROUT, *SALMO GAIRDNERII*, ON UNIFORMITY AND RATE OF GROWTH, DIET, AND PHOTOGRAPHIC SIZE-RECORDING

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Abstract

Certain techniques of measuring differences in groups of experimental fish such as might be used in testing hatchery diets or environmental factors have been developed. In an experiment of 2 months' duration, nine similar groups of fish were weighed as groups at weekly intervals, and measured individually on four occasions to determine the degree of uniformity in growth attainable under experimental conditions. The standard deviation of length for each group maintained a fairly constant relationship to the other groups. Rate of growth was rapid. The average weight in grams at any time equalled $(2.9594)(1.2378)^t$ where the exponent t is time in weeks. The 20-ingredient diet is tabulated with percentages; an over-all food conversion factor of 3 to 1 was obtained. Substitution of halibut viscera for 20 percent of the regular diet in four of the groups reduced the rate of growth significantly and was discontinued after 3 weeks. A group-photographic method of recording size was tested and found inferior to manual measuring of length for general purposes, although it had advantages in speed of obtaining a permanent record of size and general appearance. Tests of three of the length-frequency distributions showed them to be approximately normal.

Introduction

The present experiment was designed to determine the degree of uniformity in growth attainable in similar groups of fingerling fish reared in similar containers and fed equally. It also checked (1) rate of growth and food conversion; (2) effect upon growth of adding halibut viscera to the diet; (3) effectiveness of a photographic method of recording fish size; and (4) a test of normality in three length-frequency distributions.

Starting July 22, 1946, the growth of fingerling rainbow trout was observed for a period of 2 months. Approximately equal numbers of fish were held in nine uniform, nearly cubical, glass-front tanks of 80-gallon capacity, as used by Bonham and Williams (1948). Daily care of the fish included siphoning debris from the bottoms of the tanks and feeding from one to three times. The tanks were scrubbed weekly. Total weight of the fish in each tank was determined at weekly intervals. Individual lengths were taken four times during the course of the experiment, and three attempts were made to record photographically the size of a representative sample in each tank.

METHOD OF STOCKING TANKS

The fingerling fish averaging about 2 inches in length were introduced into the nine tanks from a single large trough with special effort to avoid unequal sampling. About 500 fish were dipped into a portable container from which an aliquot number of fish was counted into each tank. In order to counteract the tendency noted by Garlick (1947) and by Hewitt and Burrows (1948) toward dipping up the smaller, less active fish first, the sequence of distributing the aliquots was reversed on successive cycles so that the last tank in the previous distribution cycle would be first the next time. Netfuls consisted of fewer than seven fish so that stratification within the net did not occur. Actual numbers of fish put into each of the nine tanks at each distribution were 20, 30, 30, 30, 10, 10, and approximately 10. The number of fish in each tank was then recounted and slight inequalities corrected by shifting the necessary numbers of fish from one tank to another. At the beginning of the experiment, each of seven tanks contained 138 fish and the other two tanks, 137 fish. Further equalizations of numbers during the course of the experiment were necessitated on six occasions by the occurrence of accidents such as dropping a fish into an adjacent tank during handling, and by one accidental death. At the termination of the experiment three fish had died, so that tanks 1-5 had 137 each, and tanks 6-9 had 138 each.

METHOD OF FEEDING

The fish in all tanks received the same kind and amount of food for most of the test period. Figure 1 shows the average growth rate of the fish in all of the nine tanks and the corresponding food consumption. From August 2 to 23 inclusive, the odd-numbered tanks received the regular diet, but for the even-numbered tanks, 20 percent of the regular food was replaced with frozen halibut viscera which contained 4.06 percent oil with 166,000 international units of vitamin A per gram. The viscera had not been well preserved and emitted an offensive odor. Figure 2 shows the rates of gain in weight of odd-numbered and even-numbered tanks separately. The average weight of the fish in the even-numbered tanks at the first weighing was slightly (not significantly) greater than in the odd-numbered tanks but thereafter it was less. As long as their diet included the halibut viscera the fish in even-numbered tanks failed to gain as rapidly as those in the odd-numbered tanks which were fed regular diets. After 3 weeks, on August 23, feeding of halibut viscera was discontinued, whereupon the rate of gain of the fish in the even-numbered tanks slightly exceeded the others so that by the end of the experimental period the weights of the two groups once again did not differ significantly. Mean fish-weights for the five odd-numbered tanks were compared with those for the four even-numbered tanks (giving 7 degrees of freedom) on each of the nine consecutive weekly weighing dates, August 2 through September 27.

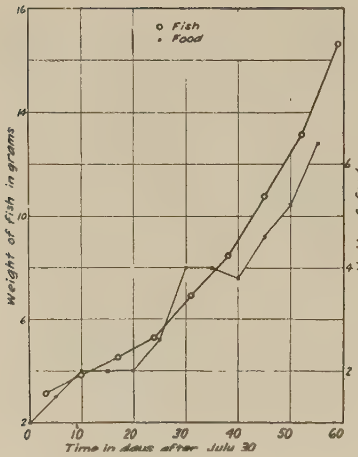

FIGURE 1.—Relationships of weight of fish in grams, and amount of food in 29.5-gram units, to time.

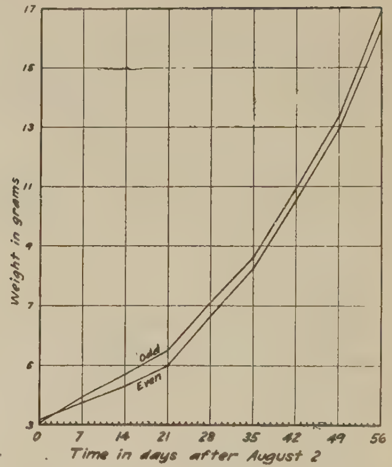

FIGURE 2. — Relationships of mean weights of fish in odd-numbered and even-numbered tanks to time.

The corresponding nine values of *t* were: 1.949, 2.744*, 8.134**, 13.04**, 4.633**, 4.496**, 3.423**, 2.462* and 2.035. Values beyond the 5 percent level bear one asterisk, and those beyond the 1 percent level, two asterisks. The difference, brought about during the first 3 weeks, was in later weeks counteracted largely, no doubt, by the slightly greater amount of food in proportion to body weight received by the fish in the even-numbered tanks.

The diet was varied from time to time. Its total composition is itemized in Table. 1. Occasional unavailability of beef liver necessitated substitution of pork-, sheep-, or fur-seal-liver, blood and tripe, or frozen salmon. Canned salmon meat was consistently used, as were also the indicated salts and plant products except for tomato pulp which was available only for the first half of the experiment. The food mixture was usually of a moist, pliable consistency. To assure that an equal amount of food would go to each tank, the allotments were apportioned in a 25-milliliter Gooch crucible with capacity of about 29.5 ± 0.1 grams of food. The perforations in the bottom of the crucible facilitated escape of air and were conducive to uniformity in filling the measure flush with the top. There were usually two feedings a day, and all the food was invariably consumed. Food was removed from the crucible with the finger and distributed over the surface of the tank by breaking it into small pieces and feeding slowly enough so that it was almost all eaten before it settled to the bottom. The efficiency of food conversion for the entire experiment was such that 3 grams of food were required to produce 1 gram of fish.

TABLE 2.—*Mean fork lengths in millimeters of rainbow trout in nine tanks on the indicated dates.*

Date	Tank number								
	1	2	3	4	5	6	7	8	9
July 26	57.76	58.49	....	....	....	....	....	....	....
July 27	....	....	58.31	....	....	....	....	....	....
August 3	....	....	....	60.90	....	....	....	....	....
August 6	....	....	....	....	62.58	62.81	....	....	....
August 7	....	....	....	....	....	....	63.33	63.52	62.94
August 19	70.89	70.47	71.39	70.20	70.60	70.38	70.63	....	....
August 20	....	....	....	....	....	....	....	70.89	70.67
September 11	89.53	88.85	90.37	....	....	....	....	....	....
September 12	....	....	....	89.20	90.29	90.18	90.12	89.67	89.66
September 27	105.08	104.28	106.00	104.57	....	....	....	....	....
September 28	....	....	....	....	104.45	105.38	104.57	103.72	103.96

TABLE 1.—*Ingredients in diets of trout for the period of the experiment.*

Item	Portion	Condition	Percentage of total
Fur seal	Liver	Frozen	0.83
Pork	Liver	Fresh	0.69
Sheep	Liver	Fresh	5.36
Beef	Liver	Fresh	39.20
Beef	Spleen	Fresh	3.23
Beef	Tripe	Fresh	3.64
Beef	Blood	Fresh	1.24
Salmon	Spawned carcasses	Frozen	1.93
Salmon	Viscera	Frozen	1.38
Salmon	Flesh	Canned	14.86
Salmon	Flesh	Dried meal	4.64
Salmon	Eggs	Air-dried meal	4.64
Oats	Whole grain	Flour	4.64
Wheat	Germ	Dried	3.09
Tomato	Pulp	Dried	1.35
Alfalfa	Entire	Dried meal	3.09
Kelp	Entire	Dried meal	1.55
Yeast		(Brewer's)	3.09
Salt		Finely ground	0.62
Oyster	Shell	Finely ground	0.93
			100.00

VARIABILITY IN LENGTH OF FISH

Individual fork lengths of fish were determined four times (Table 2) during the course of the experiment. Measurements were made using a shallow measuring cradle (Bonham and Williams, 1948) floating in the tank. Toward the close of the experiment the fish in a tank could be measured in about 20 minutes. Similarily fed groups of fish maintained uniformity throughout the experiment. Because of the rapid growth of the fish, comparisons of length could be made only for similarly fed tanks measured on the same day (Table 3). Where only two tanks could be compared the *t* test was employed, and for three or more tanks, analysis of variance was used. In no case was there a significant difference between the mean lengths of the fish in comparable tanks. Figure 3 shows that the standard deviations of length for the fish in the different tanks, (a) maintained fairly well their positions relative to one another, (b) increased during the growth of the fish, and (c) approximated a uniform rate of increase with time.

PHOTOGRAPHIC RECORDING OF LENGTH

A photographic method of recording size of fish without handling individuals was tested. The fish were held against the front glass of the aquarium by a plastic screen tightly stretched on a wooden frame 30 inches square and equipped with millimeter scales for reference during measurement. Soft rubber tubing about one-fourth inch in diameter was attached to the surface of the screen-frame to reduce the possibility of injuring fish that might be caught between the frame and the glass.

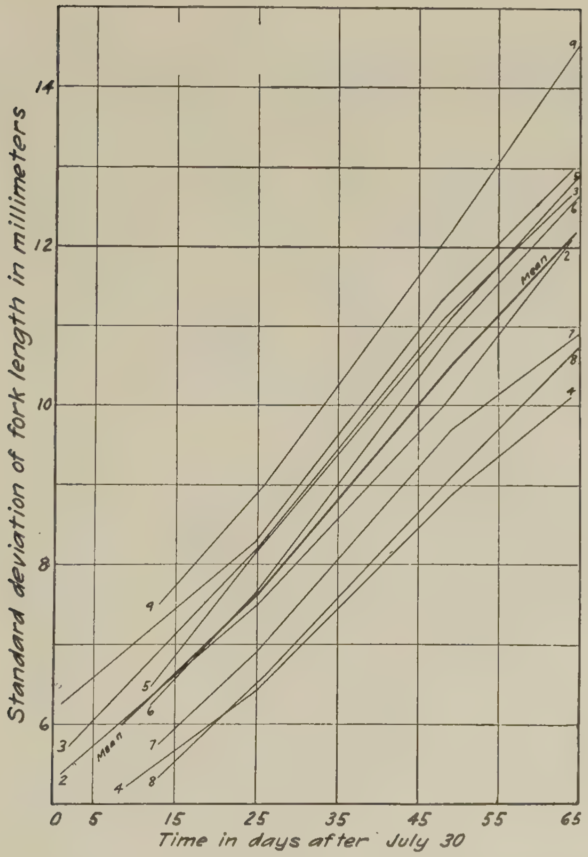

FIGURE 3.—Relationships of standard deviations of length to time. Numerals at the ends of the curves designate the tanks.

TABLE 3.—*Dates of measuring and tanks used in comparing fish lengths among tanks.*

Measurement	Date	Tank numbers
1	July 26	1 & 2
	August 7	7, 8, & 9
2	August 19	1, 3, 5, & 7
	August 19	2, 4, & 6
3	September 11	1 & 3
	September 12	4, 6, & 8
	September 12	5, 7, & 9
4	September 27	1 & 3
	September 27	2 & 4
	September 28	5, 7, & 9
	September 28	6 & 8

TABLE 4.—*Comparison by "t" test of significance of difference between lengths as determined by use of measuring board and photographs on August 19, 1946.*

Tank	Measuring board			Photographs			t
	n	Sx^2	$\bar{x}$	n	Sx^2	$\bar{x}$	
1	138	9,483	70.89	48	3,773	71.98	0.768
2	137	7,608	70.47	37	3,047	72.16	1.16
3	137	9,117	71.39	39	3,074	72.44	0.691
4	138	5,662	70.20	35	1,389	71.97	1.45
5	137	9,025	70.60	42	3,938	72.36	1.17
6	138	8,015	70.38	30	587	71.33	0.7
7	138	6,504	70.63	54	3,000	72.65	1.77
8	138	5,993	70.89	39	1,820	72.00	0.9
9	135	10,870	70.67	40	4,198	71.42	0.4
All	1236	72,410	70.682	364	24,886	72.077	3.00**

**Beyond the 1 percent level.

Photographs (Figure 4) taken August 19, 1946 were used for comparison with measurements of the living fish determined with the measuring board on August 19 and 20. The actual and photographic measurements did not differ significantly for each of the tanks considered separately, but when the data for all nine tanks were combined, the photographic measurements were greater than the actual measurements (Table 4) to a highly significant degree. The discrepancy may be the result of over-correction for suspected curvature of body out of the plane of the picture when the pictures were measured.

An evaluation of the photographic process of measurement indicated that it required more time and was less accurate than manual measurement of the living fish. Neither method resulted in appreciable injury to the fish. The superiority of the photographic method lies in the speed with which a sample can be made a matter of permanent record for future analysis, and in the fact that the depth and general appearance as well as the length of the body are recorded. If length only is to be considered, manual measurement is more desirable, especially when photographic equipment is deficient, or when immediate conclusions must be derived.

RATE OF INCREASE IN WEIGHT

All of the fish in a tank were weighed and counted each week (Table 5). Average weight of fish in all nine tanks over the period of the experiment is given by the expression:

$$W = (2.9594)(1.2378)^t,$$

where W is the weight in grams, and the exponent t is time in weeks after August 2, counting August 9 as one week.

NORMALITY OF LENGTH MEASUREMENTS

Tests to detect skewness and kurtosis as outlined by Snedecor (1940) were applied to the length measurements from Tanks 1, 2, and 9, as

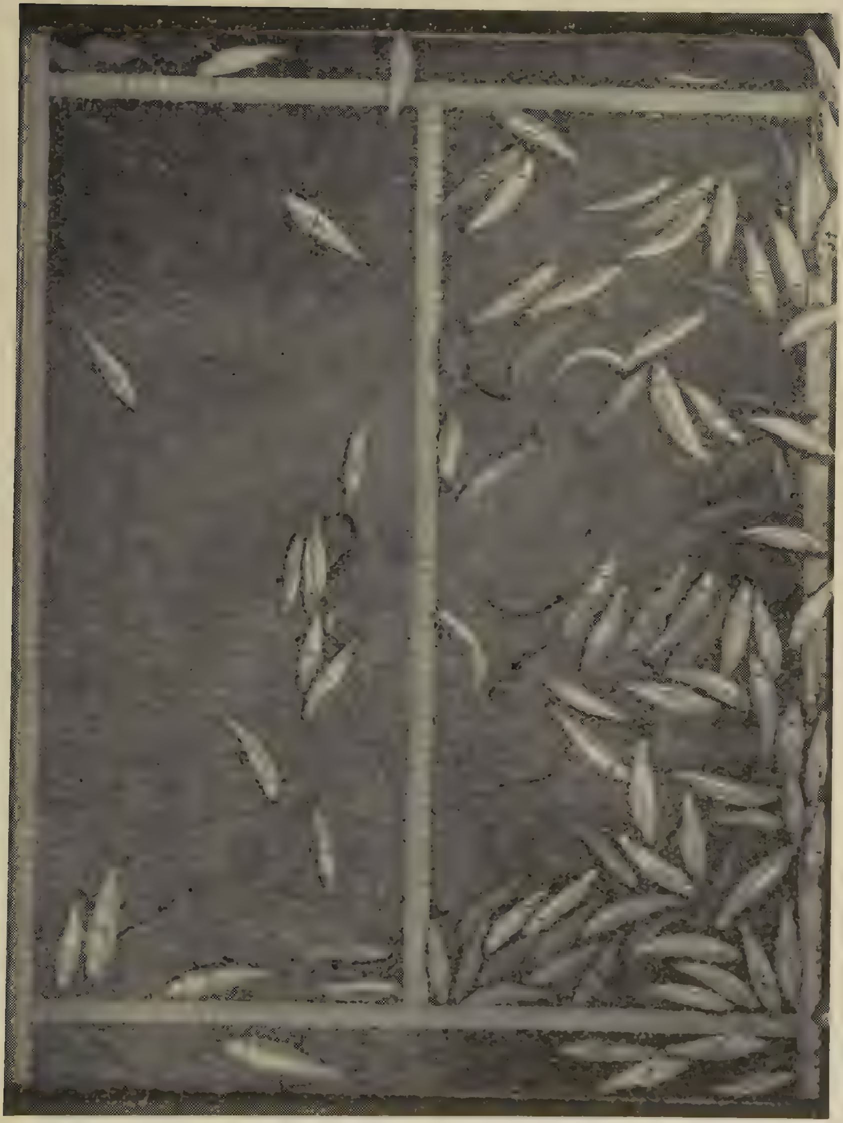

Figure 4.—Photograph of Tank 4 showing most of the fish confined by the screen against the glass. Numerals designate individuals measured on the photograph. Bottom of picture is toward the right.

TABLE 5.—*Average weight in grams of individual fish in tanks on different dates.*

Date	Tank number								
	1	2	3	4	5	6	7	8	9
August 2	3.12	3.16	3.21	3.22	3.07	3.22	3.07	3.13	2.97
August 9	4.00	3.75	4.09	3.88	4.04	3.70	3.87	3.79	3.82
August 16	4.73	4.36	4.85	4.36	4.68	4.30	4.64	4.27	4.65
August 23	5.60	5.02	5.53	4.98	5.53	4.96	5.48	5.04	5.41
August 30	7.16	6.68	7.35	6.54	6.94	6.77	7.01	6.75	7.09
September 6	8.62	8.32	8.93	8.16	8.57	8.30	8.57	8.25	8.55
September 13	10.79	10.54	11.23	10.36	10.88	10.80	10.96	10.58	10.96
September 20	13.28	12.95	13.83	12.77	13.44	13.08	13.13	12.86	13.01
September 27	17.06	16.50	17.62	16.06	16.81	16.60	16.51	16.07	16.36

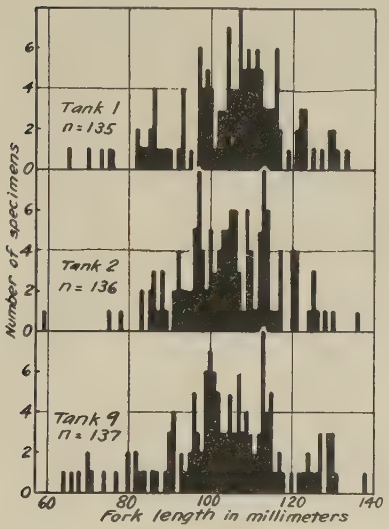

FIGURE 5.—Length-frequency histograms showing fish measurements of September 27 and 28 for Tanks 1, 2, and 9.

determined during the last measuring on September 27 (Figure 5). Negative values of g_1 for the three tanks indicated a skewness to the right with an excess of items larger than the mean. Skewness was significant in Tanks 1 and 2, respective values of P for Tanks 1, 2, and 9 being 2, 1–, and 6. Kurtosis was also uniform in type but not in extent in all three tanks. The positive values of g_2 obtained indicate that the distributions possess excessive deviations near the middle and the extremes, and are deficient in moderate deviations. Kurtosis was significant only in Tank 2 with values of P for Tanks 1, 2, and 9 being 24, 4, and 35 respectively. It was concluded that the length arrays followed the pattern of normal distribution closely enough to justify the use of statistics based on this type of distribution.

ACKNOWLEDGMENTS

The facilities of the School of Fisheries and Applied Fisheries Laboratory of the University of Washington are gratefully acknowledged. Most of the procedures and equipment were those developed by Dr. Lauren R. Donaldson. Help was received in the care, feeding, measuring, and weighing of fish from Mr. John R. Donaldson, Mrs. Lois M. Pettelle, Mr. Roger A. Baird, Dr. A. D. Welander, Mrs. D. E. Ries, Mrs. R. D. Phipps and Miss M. R. Frohlich, and in photographing the fish in the tanks from Mr. Sam Tomlin of the U. S. Army Engineers. Vitamin A and oil analyses of the halibut viscera were made by Mr. F. Bruce Sanford of the Technological Laboratory, U. S. Fish and Wildlife Service, Seattle.

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EXPERIMENTS ON THE VALUE OF WOOD YEAST *TORULA UTILIS* AS AN AQUATIC FERTILIZER

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Abstract

In 25 laboratory experiments wood yeast *Torula utilis* combined with commercial fertilizer produced from one-third more to double the phytoplankton growth produced by commercial fertilizer alone. Furthermore, this crop was produced in less time than that required by commercial fertilizer and was sustained for a longer period.

Filamentous algae did not appear in any of the tanks fertilized with wood yeast or with a combination of yeast and fertilizer but did appear in tanks fertilized with commercial fertilizer alone and in the unfertilized tanks.

Oxygen depletion was noted following fertilization with wood yeast but this may not be a serious disadvantage in pond fertilization provided the yeast is applied in small amounts or to only a portion of the pond at one time.

Introduction

The propagation of fish for food in artificial ponds is one of the oldest of agricultural practices, having been introduced by the Chinese five centuries before Christ (Neess, 1949). Before World War II vast quantities of fish were raised in Europe, especially in France and Germany, where temporarily flooded areas were rotated with field crops. Artificial ponds have long been in use in the United States, especially in the mid-west where the principal fish raised was carp. In order to increase the crop of fish, some form of artificial fertilization was often employed. Usually this was on a trial and error basis with the efficiency of the fertilizing agent being judged by the number of pounds of fish produced. Even after many years of experimental pond management, the intervening steps between the application of the fertilizer and the production of the fish is imperfectly understood.

It is, however, generally recognized that a growth of plankton is necessary for satisfactory fish production and numerous fertilizing agents have been used in attempts to stimulate this growth. Swingle (1947) recommends 100 pounds of 6-8-4 commercial fertilizer plus 10 pounds of nitrate of soda per acre of water applied as frequently as necessary to maintain a heavy growth of phytoplankton. Bernard W. Corson (unpublished data), of the New Hampshire Fish and Game Department, has used hen manure with marked success in raising smallmouth black bass (*Micropterus dolomieu dolomieu* Lacepede). Grasses, leaves, hay, various kinds of manure, cottonseed meal, and several other

TABLE 1.—*Analysis of wood yeast*[1] *Torula utilis used in fertilization experiments.*

Item	Content by weight (percentage)	Item	Content by weight (percentage)
Water	3.4–5.7	Manganese	9–16 p.p.m.
Ash	4.8 –9.1	Thiamine	5.13–14.43 mcg/g
Protein	43–54	Riboflavin	33.16–53.18 mcg/g
Fat	0.3—3.5	Niacin	153–467 mcg/g
Fiber	0.3–2.9	Pantothenic Acid	40–123 mcg/g
Carbohydrate (N.F.E.)	37.45–43.90	Biotin	2.3–8.3 mcg/g
Chlorides, as NaCl	None	Choline	1255–2150 mcg/g
Calcium	0.18–0.47		
Phosphorus	0.82–1.96		
Methionine	0.4-0.7		
Ergosterol	0.50 (one run)		

Data supplied by Dr. A. J. Wiley of the Sulphite Pulp Manufacturers' Research League, Inc.

substances have also been tried. One difficulty frequently experienced has been the appearance of a heavy growth of filamentous algae or of the formation of surface film, both of which are detrimental to fertilized ponds.

In the fall of 1946, Dr. Joseph Seiberlich of the University of New Hampshire Engineering Experiment Station suggested that the Biological Institute undertake some experimental work with wood yeast *(Torula utilis)* to determine whether or not it could be used in the fertilization of fish ponds. It was suggested that wood yeast had several advantages: (a) it has a very high vitamin content (8 vitamins—the B complex is especially strong); (b) it has a high protein content, ranging from 48 to 54 percent, and a non-protein nitrogen content of approximately 8.15 percent; (c) although not yet produced commercially, it is predicted that it can be produced at reasonable cost; and (d) it can be produced in unlimited quantities since it is grown on wood waste including the discharge from pulp and paper mills. In order to explore the possibilities of wood yeast as an aquatic fertilizer, experimental work was started in September, 1946. The wood yeast provided for the experiments was a light yellowish meal, somewhat sweet in taste and granular in texture, with the analysis shown in Table 1.

METHODS

These experiments were organized to determine the relative increase of plankton production by the use of wood yeast, commercial fertilizer, and a combination of wood yeast and commercial fertilizer. For this purpose, glass tanks holding 1 cubic foot of water were arranged in groups of four. Tank "A" was fertilized with 1 gram of wood yeast; tank "B" with 1 gram of 5-10-5 commercial fertilizer; tank "C" with ½ gram of wood yeast and ½ gram of commercial fertilizer; tank "D" was used as a control without any fertilizing agent. Water for these experiments was secured from a pool in the college greenhouse and was strained through a fine grade of cheesecloth before being placed in the tanks. The tanks were arranged in such a way that all received approximately the same amount of sunlight and were kept, as far as possible, at a uniform temperature of 20° C.

Since the primary purpose of fertilizing a pond is to stimulate the growth of chlorophyll-bearing organisms, a rapid and accurate method for determining the amount of this growth was sought. Photoelectric cells have been used for some time in determining turbidity. It seemed possible to apply this principle in measuring the amount of plankton present in the experimental tanks. Therefore, a turbidimeter, based on a General Electric photographic light meter, was constructed. A tube of plastic 20 by 25 by 150 millimeters was made to fit over the end of this light meter. This tube was blackened on the outside in order to exclude all light except that entering through the end. The meter, tube, and source of light were arranged in such a way that the light would shine down the tube. The equipment was then standardized by filling the tube with 50 milliliters of distilled water and adjusting the light so that the pointer on the light meter indicated 70 candle power. This water was then replaced with 50 milliliters of water taken from the center of the tank to be checked. The loss of candle power noted was a measurement of the relative turbidity in each tank. This instrument was sensitive enough to measure changes in the amount of chlorophyll-bearing organisms which could scarcely be detected by the naked eye. It was not effective, however, in measuring the abundance of the transparent zooplankton since these produced little effect on the light meter.

Types of Organisms Occurring

No attempt was made to trace the day by day changes in the species produced in the several tanks since greater importance was attached to the total amount of plankton produced. The greatest percentage of the phytoplankton in the experimental tanks consisted of *Chlorella, Scenedesmus, Chlamydomonas,* desmids, some *Protococcus,* and unidentified blue-green algae. The zooplankton included a great variety of flagellates and ciliated forms with *Paramoccia* and chlorophyll-bearing forms, such as *Euglena,* always abundant. Rotifers and macroscopic crustaceans were usually not evident at the beginning of an experiment and frequently could not be counted until the eighth or tenth day when rotifers appeared in numbers in the fertilized tanks followed by *Daphnia* and a few *Cyclops.* As the phytoplankton started to decline, *Daphnia* frequently became abundant and dominated the zooplankton. This was more noticeable in the tanks fertilized with yeast.

Measurements of Results

The results of several experiments in which a single application of wood yeast, of commercial fertilizer, or a combination of yeast and commercial fertilizer was used were not always the same. The amount of sunlight during the first few days following fertilization was an important factor in the development of the phytoplankton which indirectly affected the zooplankton. The results of several experiments in which the zooplankters were counted in the Sedgwick-Rafter cell and the turbidity measured by the turbidimeter were as follows: The tanks (A) fertilized with 1 gram of yeast produced an average maximum of 65 zooplankters per milliliter in 16 days and then declined so that by the end of 30 days the number was reduced to 15 or 16 per milliliter. The average maximum amount of light absorbed was 30 candle power, the peak of absorption being reached in from 9 to 12 days.

In the tanks (B) to which only commercial fertilizer was added (1 gram of 5-10-5 per cubic foot) the increase of zooplankters was always more gradual than in the tanks containing yeast alone. The average maximum of 42.5 organisms per milliliter was reached in about 30 days and the decline was also more gradual with number of plankters seldom dropping below 15 to 17.5 per milliliter. The average maximum amount of light absorbed was 22 candle power with the peak of absorption being reached in 25 to 30 days.

In the tanks (C) containing one-half gram of yeast and one-half gram of commercial fertilizer the average maximum of 52.5 plankters per milliliter was reached in 18 days. This number declined to 15 or 16 in 35 days. The average maximum amount of light absorbed was 32 candle power with the peak of absorption being reached in 12 to 14 days.

The check tanks (D) varied from 4 to 20 zooplankters per milliliter and the light absorption ranged from 3 to 10 candle power.

In fish-pond management it is the practice to fertilize at regular intervals during the growing season. Therefore a series of experiments was set up to determine the results of refertilization. For this purpose four tanks were used as in the preceding experiments, each tank containing 1 cubic foot of water. The amount of light absorbed by the water in each tank was ascertained by the method described above before any fertilizer was applied. This absorption averaged from 3 to 5 candle power. Following these determinations there was added, once each week for 8 weeks, to tank A, 1 gram of wood yeast; to tank B, 1 gram of 5-10-5 commercial fertilizer; to tank C, ½ gram of wood yeast and ½ gram of commercial fertilizer. Tank D was left unfertilized as a control.

After 3 weeks, the tank (A) to which yeast alone was added was lime green in color and the growth was so dense that it was impossible to see macroscopic zooplankton. On an average of 40 days after the experiment was started, the quantity of plankton had reached its maximum density with an absorption of 41 candle power. From this point to the end of the experiment, the numbers of plankters increased and decreased in short-lived pulses but seldom reached again the maximum peak.

In the tank (B) to which 1 gram of commercial fertilizer was added each week for a period of 8 weeks, the response was about the same as when only one application of fertilizer was used. The maximum absorption of from 18 to 22 candle power was reached in from 25 to 30 days.

In the tank (C) fertilized with ½ gram of wood yeast and ½ gram of commercial fertilizer there was an average light absorption of 17 candle power at the end of 3 weeks and 30 candle power by the end of 7 weeks. By the end of 4 weeks there were great numbers of macroscopic plankters present. The turbidity continued to become more pronounced each week until by the end of the eighth week an average of 54 candle power was absorbed. The combination of fertilizer and wood yeast applied at weekly intervals produced a condition which was more favorable for the production of both plants and animals than either yeast alone or commercial fertilizer alone. No filamentous algae developed in the tank fertilized with wood yeast and commercial fertilizer nor in the tank fertilized with wood yeast alone.

The control tank (D) showed a slow increase in light absorption to 8 or 10 candle power. A mat of algae developed on the bottom of the tank and no macroscopic zooplankters were discovered at any time. In all tanks the first appearance of phytoplankton was conditioned by the amount of sunlight.

An analysis of the results of these experiments shows that a combination of wood yeast and commercial fertilizer produced more than twice the amount of plankton produced by commercial fertilizer alone when applied at weekly intervals. The combination also produced nearly a third more plankton as measured by the turbidimeter and more zooplankton as counted in the Sedgwick-Rafter cell than yeast alone in the experiments in which there was a single application of fertilizer. The reason for this increase is probably the sustained growth of phytoplankton which furnished a more abundant food supply for the small animals.

THE CHEMICAL EFFECT OF FERTILIZATION WITH WOOD YEAST

During these experiments with wood yeast, a check was kept on the oxygen, the carbon dioxide, and the pH in the experimental tanks. Also, as a matter of routine, general weather conditions, air temperature, and water temperature were recorded. The water temperatures ranged from 22 to 25° C.

Early in the experiments a depletion of oxygen was noted in tanks fertilized with wood yeast. So striking and so rapid was this loss that special experiments were set up to determine the extent of oxygen depletion. Most of these determinations were made by the Winkler method although the Amidol colorimetric method was also used. Water in the untreated experimental tanks contained, as a rule, more than 5.0 p.p.m. of oxygen. It was noted that, in from 2 to 3 hours after the yeast was added at the rate of 1 gram per cubic foot of water, there was a drop of 1 p.p.m. of oxygen and at the end of 24 hours there was a total drop of 3 p.p.m. It was also observed that the greater amount of yeast used, the more rapid was the oxygen depletion. The maximum oxygen depletion (oxygen content less than 1 p.p.m.) was reached on the fourth or fifth day after the addition of the yeast; then the oxygen content gradually returned to normal.

When a small quantity of the wood yeast was mixed with water and kept in a warm place for a few hours, budding yeast cells were readily located. In fact, it was shown that about half of the yeast cells were alive. Live yeast cells were also recovered from the experimental tanks 48 hours after fertilization and were grown on Sabouraud's agar medium. According to Prescott and Dunn (1940) yeast will live in water for a period of about 6 days using material from its own substance (autophagy). This process involves the utilization of oxygen which is taken from the surrounding water. If the yeast is killed by placing it in a drying oven for a sufficient length of time, there is still a marked reduction of oxygen. Autophagy depends, according to Effront, not on the cells but on the enzymes which are formed in the cells when placed in inanition (Guilliermond, 1920, p. 105).

In view of these observations, it is believed that the rapid lowering of the oxygen in yeast-treated water is probably caused either by the growth of yeast in the water or (and) by the action of the enzymes formed in the yeast cells. On the basis of the results of oxygen determinations it seems probable that some of the wood yeast cells were alive and active for the first 3 or 4 days after inoculation. Having, however, an insufficient amount of food available their activity is short-lived and is followed by an upswing of oxygen caused by the photosynthetic activity of the phytoplankton.

Where a combination of yeast and fertilizer was used, there was always a drop in the oxygen content at first. However, as there were only half the number of yeast cells in these experiments, in contrast to those in which only yeast was used, the upsurge of phytoplankton was sufficient to carry the oxygen at a relatively high level and in some cases higher than at the beginning of the experiment. It is felt that the reduction of oxygen must be taken into consideration in the use of wood yeast as a pond fertilizer and if it is used alone it must be applied in small quantities or to only a portion of the pond at one time so as not to cause asphyxiation of fish in the pond. In contrast to the yeast alone, the combination of one-half yeast and one-half commercial fertilizer could be applied without any serious risk to fish life.

Carbon dioxide like oxygen, showed a great deal of variation. In tanks to which there had been a single application of yeast or yeast plus fertilizer, the drop in oxygen was accompanied by an upswing of carbon dioxide. This increase was usually not more than 15 to 20 p.p.m. In all of the fertilized tanks, the pH remained well above 7.0.

Acknowledgments

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FURTHER OBSERVATIONS ON THE USE OF HYBRID SUNFISH IN STOCKING SMALL PONDS[1]

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Abstract

A total of 16,075 hybrid sunfish (*Lepomis microlophus,* female x *L. macrochirus,* male) were placed in 78 small ponds in southwestern Indiana in November, 1947. During the summer of 1949 each pond was seined. All together 722 hybrid sunfish were taken from 62 ponds. Of that total, 317 individuals were caught from 29 ponds in which no other fish were present and the remaining 405 were taken from 33 ponds that contained other kinds of fish. The remaining 16 ponds yielded no hybrids during seining operations.

In general, the hybrid sunfish from those 29 ponds in which they had no competition from other species grew faster and were relatively heavier for their length, especially in the larger size groups, than those taken from the other ponds. The hybrids were relatively larger and heavier for their length than individuals of the same age groups in either of the parent species taken from similar ponds. Data on the fork lengths and total lengths of hybrid sunfish and on respective average weights are given. The presence of other fish in the ponds with the hybrids was due largely to intentional introduction rather than to natural invasion.

Introduction

The pioneer work on the use of hybrid sunfish for stocking small ponds has been outlined by Ricker (1948). The cross selected for that first practical trial in 1942 was between the bluegill, *Lepomis macrochirus*, and the redear sunfish or shellcracker, *L. microlophus*. Male bluegills and female redears were placed in a fish hatchery pond early in the spring and the resulting offspring used to stock another hatchery pond as well as 10 small ponds scattered through four counties in southern Indiana. The progress of the hybrids in those ponds was followed for several years and that information furnished the basis for Ricker's report. Because there was a series of uncontrollable circumstances, such as the "natural" infestation of the ponds with other, and oftentimes undesirable, species of fish, the intentional stocking of such species, the failure of dams, transfer of property ownership, etc., that series of experiments was abandoned. Four of the ponds stocked by Ricker in 1942 yielded no hybrids when they were extensively seined in 1949. Two others, as well as the hatchery pond, had been drained. The fish populations of three of the ponds were killed with rotenone and no hybrids were recovered from any of them. The remaining pond (Lincoln City Pond) was drained in 1943 and the hybrids removed to stock other ponds.

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The same cross as the one used by Ricker in 1942 has been repeated three additional times in different ponds with creditable success in each case. In one of those instances, the parent fish were allowed to remain in the same pond over winter and reproduced successfully each of 3 successive years. Thus that cross has been made experimentally a total of six times in Indiana. Upon examination of 428 F_1 bluegill x redear sunfish hybrids for the determination of sex, Ricker found that nine individuals (2.1 percent) were females and the remaining fish were males. The reciprocal cross, using male redear sunfish and female bluegills, has been tested under conditions similar to those described by Ricker (1948) three separate times without obtaining a single offspring in any instance. In all cases the parent fish for both crosses came from the same stock.

Such differences in the results of reciprocal crosses between animals of the same two species are not uncommon. In their studies on hybridization among different species of sunfishes, Hubbs and Hubbs (1933) found that the first generation offspring were predominantly male. The crosses referred to were between the green sunfish (*Lepomis cyanellus*) and the pumpkinseed (*L. gibbosus*); the green sunfish and the bluegill (*L. macrochirus*); and the green sunfish and the longear sunfish (*L. megalotis*). The sex ratios observed in naturally-reared specimens of those hybrids were 295 males to 17 females (95 percent males), 47 males to 11 females (81 percent males), and 20 males to 2 females (91 percent males), respectively. These sex ratios all show a greater abundance of females than those in the redear sunfish x bluegill hybrids reported by Ricker (1948). Further, Hubbs and Hubbs (1932) succeeded in obtaining hybrids under aquarium conditions by crossing a male pumpkinseed with a female green sunfish and also were so fortunate as to obtain offspring from the reciprocal cross (male green sunfish x female pumpkinseed). Sturtevant (1920) found that crosses between male *Drosophila simulans* and female *D. melanogaster* produced only female offspring except under particular circumstances involving the chromosomal constitution of the mother, whereas the reciprocal cross with the same species usually produced only male offspring. Sturtevant also pointed out that all hybrids of both classes were sterile and that the gonads were rudimentary.

It is generally accepted that any hybrid inherits its chromosomes from both parents, but its cytoplasm only from the mother. The properties of that cytoplasm are not independent of the chromosomes but rather are predetermined by the chromosomes and are already present in the egg prior to meiotic divisions and fertilization. As such they exert what is known as the maternal effect on the offspring. Dobzhansky (1941:319) has stated the concept more concretely:

> . . . The sterility of the hybrids in question is due to interactions between the chromosomal constitution of the hybrid itself and the properties of the cytoplasm of the egg from which it develops, always keeping in mind that the properties of the latter are determined by the chromosomal constitution of the mother.

Although the chromosomal constitution of neither the bluegill nor the redear sunfish has been worked out, Haldane (1922) formulated a rule that furnishes a clue:

> When in the F_1 offspring of a cross between two animal races, one sex is absent, rare, or sterile, that sex is the heteorzygous sex.

Thus the male bluegill is probably homozygous for sex and the female redear heterozygous.

Both Ricker (1948) and Hubbs and Hubbs (1933) found that the characteristic of predominant maleness was carried on into the F_2 generation of hybrid sunfishes.

Rearing and Stocking Hybrid Sunfish

Early in the spring of 1947, a new series of field experiments involving the stocking, growth rate, and survival of hybrid sunfish in small ponds was inaugurated on a much broader scale than in former trials. At that time the east rearing pond below Yellowwood Lake in Yellowwood State Forest, about 13 miles east of Bloomington, was set aside for the rearing of hybrid sunfish. Eight male bluegills, ranging in fork length from 7 to 9 inches, were trapped from Yellowwood Lake and placed in the rearing pond about May 1 along with 11 female redear sunfish of similar size that had been brought in from Round Lake, Whitley County, Indiana. Those fish spawned successfully and in November 1947, 16,075 young hybrid sunfish were removed and used for planting. At that time, however, an unknown number (several thousand) young hybrids along with the parent stock were allowed to remain in the pond over winter. Those remaining hybrids were removed in 1948 and used in other experiments.

As the young hybrid sunfish were taken from the pond they were distributed to a total of 78 small ponds in five counties in southern Indiana (Table 1). All of the ponds, with one exception, had been constructed

Table 1.—*The distribution of young-of-the-year hybrid sunfish in five counties in southwestern Indiana indicating the number of ponds, their total combined surface area, and the total number of fish stocked*

County	Number of ponds	Combined area of ponds (acres)	Total number of fish stocked
Daviess	2	1.3	1,000
Gibson	1	0.3	150
Knox	59	18.4	9,450
Sullivan	3	1.0	750
Vanderburgh	13	10.0	4,725
Total	78	31.0	16,075

that year under the supervision of the U. S. Soil Conservation Service. The exception was a pond that had been built in 1941 and treated with rotenone in August 1947 in an attempt to rid it of black bullheads.

In the selection of the ponds for stocking with hybrid sunfish we endeavored to include as wide a variety of sites as possible. The ponds ranged in size from 0.1 to 1.4 acres but were predominantly 0.2 to 0.4 acre in extent. The maximum depths of the ponds ranged from 6 to 12 feet. Some of the pond sites were in watersheds entirely devoted to permanent pastureland, others in watersheds largely in cultivation, and still others in areas somewhat intermediate between those two extremes. A few ponds were located in ungrazed wood lots, and a few others in orchards. At the time the ponds were selected for planting we were assured that the owners would fence the ponds, wherever necessary, so that they would not be accessible to livestock. By the end of the second summer after stocking (1949), however, some of the ponds had become badly silted and a few had literally been converted into wallows for livestock. At the time the hybrid sunfish were planted it was believed that they were to be the only fish put in the pond. All of the ponds were stocked at a rate of 500 fish per acre of surface area. The hybrids used in stocking ranged in fork length from 50 to 70 millimeters and had an average weight of 230 grams per hundred individuals.

SURVIVAL OF STOCKED FISH

During the summer of 1949, each of the ponds that had been stocked with hybrid sunfish in 1947 was checked so that the rate of fish growth and other pertinent data might be obtained. Each pond was seined with a quarter-inch-square mesh seine either 30 or 50 feet long and 6 feet deep depending on the extent and depth of seinable water. Each seine was fitted with a bag 8 feet long and 6 feet deep that would trail out in back for a distance of 6 feet. With such equipment it was possible to cover a major part of each pond and thus get an adequate sample of the fishes present. If a single haul yielded what was believed to be an adequate sample, no further seining was done. If, however, the yield of the first haul, or even that of the second and third hauls, was not satisfactory, seining was continued until either an adequate sample was obtained or further seining was considered to be useless.

Of the 78 ponds checked during 1949, 29 (37.2 percent) yielded only hybrid sunfish, 33 (42.3 percent) yielded hybrid sunfish along with an assortment of other kinds of fish, 6 (7.7 percent) yielded other species of fish but no hybrids, and 10 (12.8 percent) yielded no fish at all. In the last category, if the pond was seined, we took no fish either because there were apparently no fish in the pond or because physical conditions prevented adequate sampling. On two occasions it was found that the orchards which occupied most of the entire watershed had been sprayed at least eight or nine times during the spring and summer of 1949 (and perhaps 1948 as well) with DDT, sulphur and lime, lead arsenate, etc., for pest control. In those instances the toxic substances had apparently been washed into the ponds during rainstorms in sufficient quantities to kill all the fish. Three other ponds had become little more than hog wallows and no attempt was made to seine them.

All together a total of 722 hybrid sunfish were taken by seining the 62 ponds in which they occurred. Of that total, 317 individuals (43.9 percent) were caught from the 29 ponds in which no other fish were present and the remaining 405 hybrids (56.1 percent) were taken from the 33 ponds in which other species of fish were taken. Those fish ranged in fork length from 88 to 211 millimeters and in weight from 11 to 328 grams.

LENGTH-WEIGHT RELATIONSHIP

The rate of growth of fishes is largely a reflection of the availability of suitable food material. When an abundance of the proper kinds of food is available, fish grow rapidly and reach a large size in a relatively short period of time. If, however, the competition for food is increased by an increase in numbers of the existing population or by the introduction of competitive species of fish, the growth rate will be slowed down accordingly. Further, it is generally agreed that fishes on an ample diet

TABLE 2.—*Fork length-weight and total length-weight relationships in bluegill x redear sunfish hybrids collected in 1949.*

Length group, millimeters	Fish measured to fork length		Fish measured to total length	
	Number of fish	Average weight (grams)	Number of fish	Average weight (grams)
90	2	13.5	..	....
95	2	19.0	1	11
100	12	20.2	2	16.5
105	26	23.3	9	18.3
110	22	27.8	21	22.7
115	23	31.0	21	25.6
120	46	37.0	24	29.8
125	26	42.0	36	35.3
130	40	47.9	31	38.7
135	35	55.6	35	45.1
140	55	63.6	30	51.1
145	73	70.3	45	57.9
150	51	80.8	59	66.9
155	49	91.1	60	72.3
160	33	102.6	50	83.7
165	31	121.5	48	94.0
170	40	140.1	26	104.8
175	49	156.3	30	123.7
180	45	169.1	42	139.8
185	36	190.1	58	159.7
190	13	203.7	38	172.9
195	11	222.8	29	191.3
200	1	192	13	201.2
205	..	.....	12	224.1
210	1	328	..	.....
215	..	.....	1	192
220	..	.....	1	328
Totals	722		722	

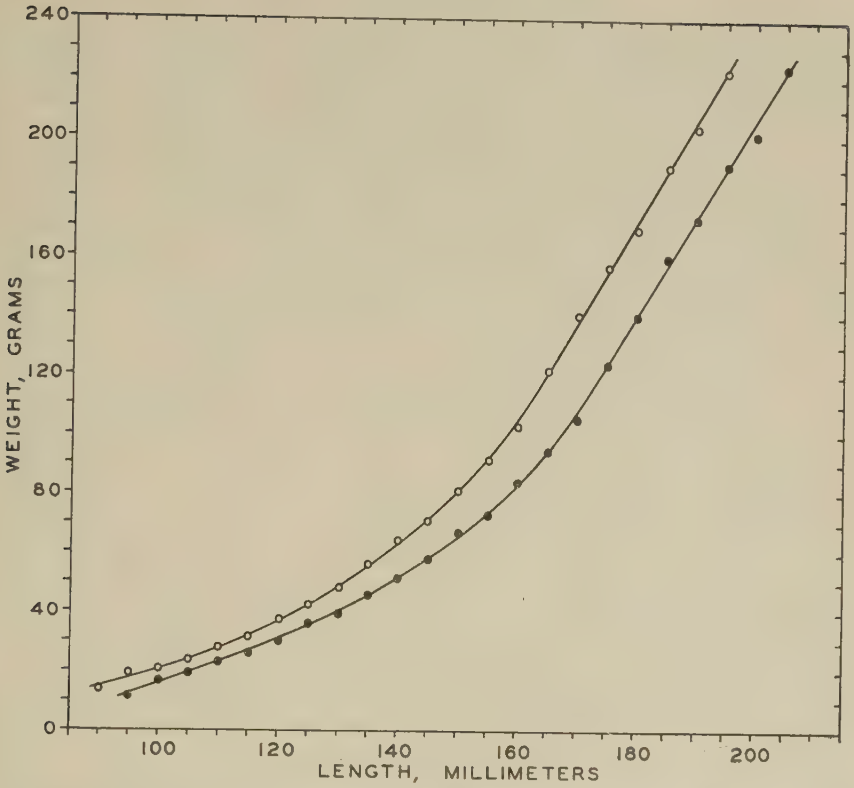

FIGURE 1.—Average fork lengths, total lengths, and weights of bluegill x redear sunfish hybrids from Indiana ponds, 1949. The upper curve (open circles) indicates the fork length-weight relationship, the lower (solid dots), the total length-weight relationship. Both curves were fitted by inspection.

(with little or no outside competition) will be relatively heavier for their length than those which are less adequately fed (increased competition).

That hybrid sunfish are particularly suited to rapid growth is perhaps due to three characteristics. First, it has been suggested by Hubbs and Hubbs (1933) that hybrid sunfish are generally infertile and for that reason should not be able to overpopulate any pond in which they are the only type of fish present. However, it was demonstrated by Ricker (1948) that approximately 2 percent of the F_1 generation of bluegill-redear sunfish hybrids are females that can produce eggs. With this reduced reproductive potential, it is still doubtful that such hybrids could give rise to enough offspring to cause undue crowding. Secondly, inasmuch as bluegill x redear sunfish hybrids can reproduce, even though only to a limited extent, that small reproduction might be ample to preclude any restocking once the population has become established. Thus there would continue to be an ample supply of food to accommodate the entire population. Thirdly, an increased growth in hybrid sunfishes due to "hybrid vigor" has been demonstrated by Hubbs and Hubbs (1931) and any such increased growth would be advantageous.

In compiling the data on the relationship between length and weight of the 722 bluegill x redear hybrids caught during the summer of 1949, both the fork lengths and the total lengths of all fish were placed in 5-millimeter groups and the average weights in grams of all fish in each such group calculated. The data on the number of fish in each length group for each category of fork length and total length together with their average weights are shown in Table 2 and Figure 1.

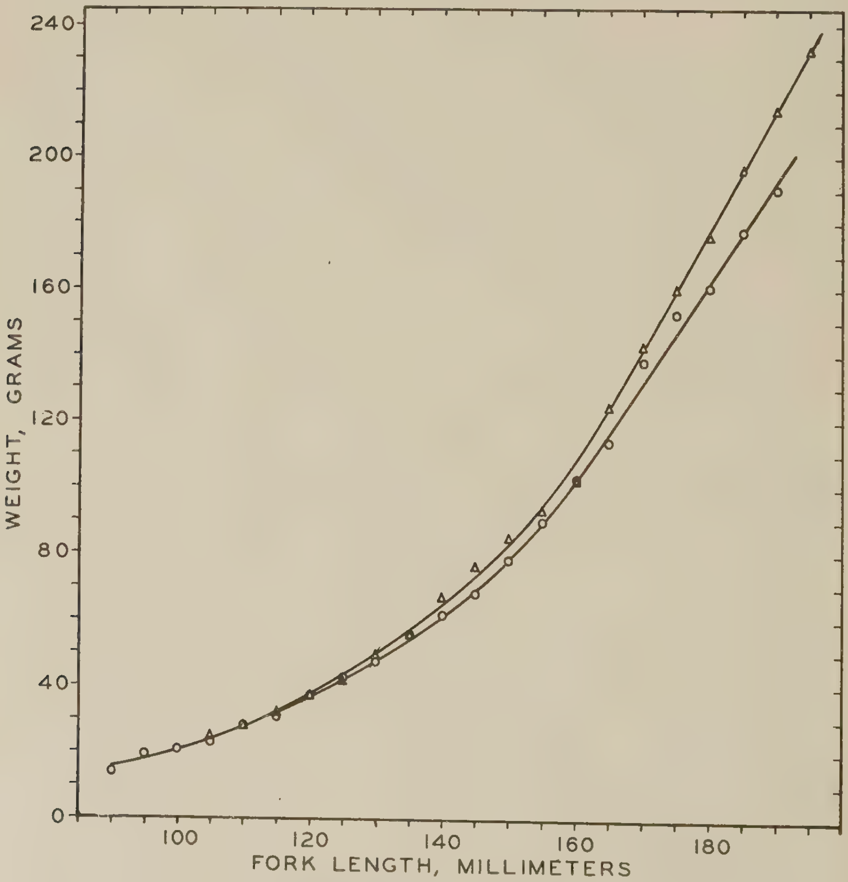

FIGURE 2.—Fork length-weight relationship in bluegill x redear sunfish hybrids both in competition with other fish and with no other kinds present. The upper curve (triangles) indicates the length-weight relationship of fish with no other kinds competing, the lower (open circles), the hybrids in competition.

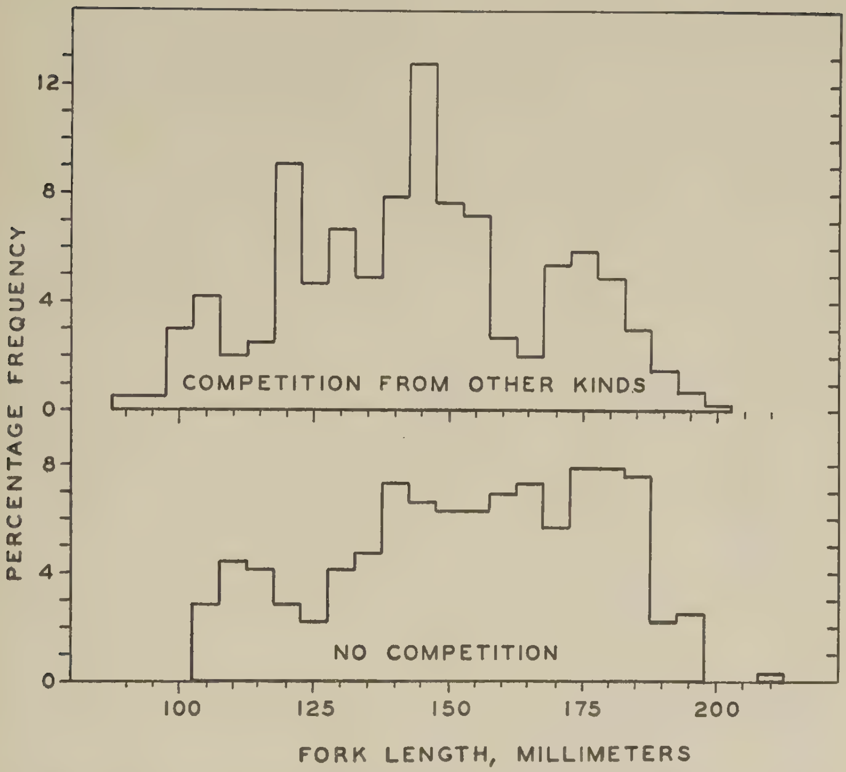

FIGURE 3.—Comparison of length frequency distribution of bluegill x redear sunfish hybrids with and without competition from other kinds of fish. Data are expressed as percentage of total fish which fall in each interval.

In general, the hybrid sunfish from the 29 ponds in which they had no competition from other species grew faster and were relatively heavier for their length, especially in the larger size groups, than did those from the 34 ponds in which there were other kinds of fish (Table 3, Figure 2). In addition, the length distributions of hybrids from both categories indicate that the fish in competition did not generally reach such large sizes as those without competition (Table 3, Figure 3). The average fork length for the hybrids with no outside competition was 154 millimeters whereas that average for the fish in competition was only 144 millimeters.

Perhaps one of the best manifestations of hybrid vigor is illustrated by a comparison of the length-weight curves of the hybrid sunfish with similar curves for each of the parent species. The data on the lengths and weights of the bluegills and redear sunfish were collected from

TABLE 3.—*Length-weight relationships in bluegill x redear sunfish hybrids with and without competition from other kinds of fish. Collections made in 1949.*

Fork length, millimeters	Hybrid sunfish with no other kinds competing		Hybrid sunfish competing with other kinds	
	Number of fish	Average weight (grams)	Number of fish	Average weight (grams)
90	2	13.5	..	....
95	2	19.0	..	....
100	12	20.2	..	....
105	17	22.9	9	24.2
110	8	28.0	14	27.6
115	10	30.7	13	31.2
120	37	37.0	9	37.0
125	19	42.5	7	41.3
130	27	47.3	13	49.1
135	20	55.8	15	55.2
140	32	61.2	23	66.9
145	52	67.9	21	76.0
150	31	78.5	20	84.4
155	29	89.9	20	92.7
160	11	102.8	22	102.5
165	8	113.3	23	124.4
170	22	138.0	18	142.6
175	24	152.4	25	160.1
180	20	160.4	25	176.0
185	12	177.7	24	196.3
190	6	190.8	7	214.7
195	3	198.0	8	232.1
200	1	192	..	.....
205	..	.....	..	.....
210	..	.....	1	328
Total	405		317	

various ponds in southern Indiana by the same techniques as described for the hybrids. The ponds containing bluegills and/or redear sunfish usually also contained one of the black basses. During the course of the summer of 1949 a total of 49 ponds containing bluegills and 27 ponds that contained redears were seined. Only those bluegills and redear sunfish that had attained a length as great or greater than that of the smallest hybrid sunfish were used in the comparisons (Table 4, Figure 4). These data on bluegills and redear sunfish are prodably more comparable than data from similar kinds of fish in other parts of the state inasmuch as they were collected from fish that were living in much the same type of environment as the hybrids. The selection of ponds for stocking bluegills and redear sunfish was made on the same basis as that for the hybrids. The 49 ponds from which bluegills were taken were located in six counties as follows: Dubois County — 2 ponds; Knox County — 21 ponds; Spencer County — 4 ponds; and Washington County — 10 ponds. The 27 ponds from which redear sunfish were seined were situated in the following five counties: Dubois County—eight ponds; Knox County—seven ponds; Spencer County—seven ponds; Vanderburgh County—one pond; and Washington County—four ponds.

The length-weight relationships for hybrid sunfish, bluegills, and redear sunfish indicate that under similar environmental conditions the hybrid is considerably heavier for its length than either of the parent

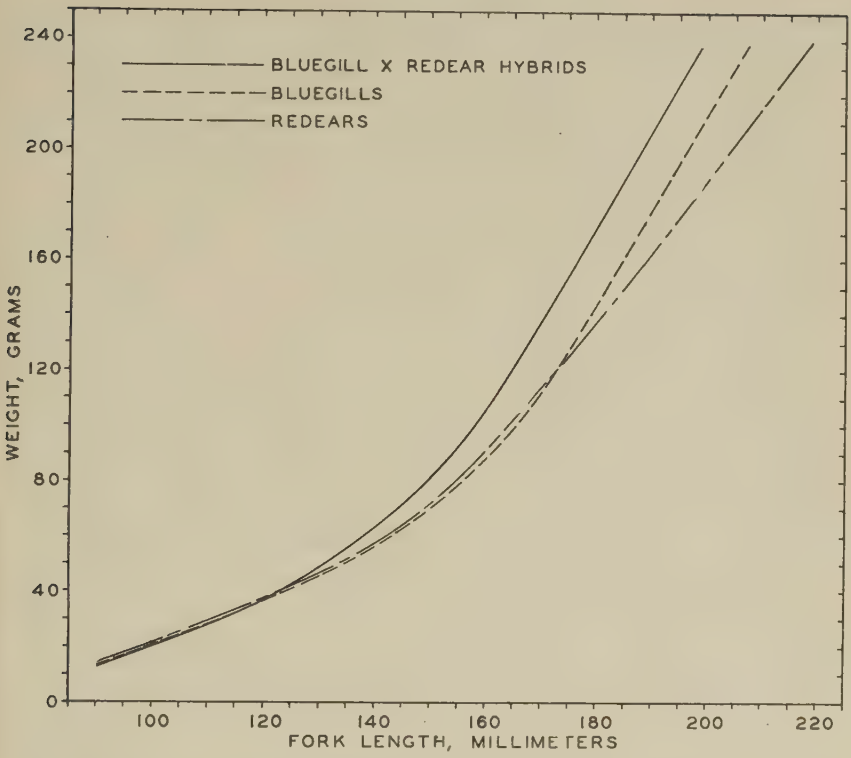

FIGURE 4.—Fork length-weight relationship of bluegill x redear sunfish hybrids, bluegills, and redears. The curves are based on the data in Table 4.

species after a fork length of about 160 millimeters has been reached. The data reported by Ricker (1948) on fish from the Bert Clark Pond in Knox County show that hybrid sunfish may reach phenomenal sizes in rather short periods of time. These fish were 237 and 248 millimeters long (fork length) and weighed 455 and 467 grams respectively in April, 1946 at the beginning of their fifth summer of life. Another such hybrid had attained a fork length of 251 millimeters and a weight of 435 grams at an age of 41 months. Such a rate of growth considerably exceeds that observed among either bluegills or redear sunfish taken from any small ponds in Indiana. Comparable data on 50 redear sunfish taken from the A. L. Lutz Pond in Vanderburgh County in June, 1949 indicate that those fish had an average fork length of slightly more than 8.5 inches (219 millimeters) and an average weight of 9-10 ounces (270 grams). The largest of the lot was 227 millimeters long and weighed

TABLE 4.—*Comparison of length-weight relationships in bluegill x redear sunfish hybrids, bluegills, and redear sunfish. Collections made in 1949.*

Fork length, millimeters	Hybrid sunfish		Bluegills		Redear sunfish	
	Number	Average weight	Number	Average weight	Number	Average weight
90	2	13.5	32	14.1	15	14.1
95	2	19.0	37	15.2	10	17.9
100	12	20.2	25	18.4	18	21.2
105	26	23.3	42	23.1	13	23.4
110	22	27.8	36	26.2	18	28.7
115	23	31.0	37	30.4	7	32.3
120	46	37.0	37	35.7	8	36.1
125	26	42.0	39	40.4	7	42.9
130	40	47.9	30	45.0	1	44
135	35	55.6	19	55.2	6	54.2
140	55	63.6	22	63.5	6	52.3
145	73	70.3	29	73.3	6	60.2
150	51	80.8	27	80.7	5	72.2
155	49	91.1	15	93.5	10	82.7
160	33	102.6	12	95.0	7	85.9
165	31	121.5	10	108.3	8	108.9
170	40	140.1	9	114.2	14	115.8
175	49	156.3	4	159.8	11	126.1
180	45	169.1	2	160.5	13	133.7
185	36	190.1	..	.....	9	151.2
190	13	203.7	3	202.7	6	156.5
195	11	222.8	..	.....	7	165.6
200	1	192	1	244	1	177
205	..	.....	..	.....	1	204
210	1	328	..	.....	1	208
215	..	.....	..	.....	..	.....
220	..	.....	..	.....	1	243
225	..	.....	..	.....	..	.....
230	..	.....	..	.....	..	.....
235	..	.....	..	.....	1	306
Total	722		496		210	

315 grams. Those fish had been planted, along with some largemouth bass, as fingerlings in October, 1945 and were beginning their fifth summer of life.

INTRODUCTION OF OTHER SPECIES OF FISH

Of the 78 ponds that had been stocked with hybrid sunfish in November, 1947, a total of 39 (50 percent) contained other kinds of fish when seined in 1949. Upon questioning the owners of 29 of those ponds we found that 26 of them (67 percent of those ponds with other kinds of fish present) had intentionally introduced other kinds of fish into the ponds. In some instances only such fish as largemouth bass (*Micropterus salmoides*) and bluegills had been planted. In others, black and/or white crappies *(Pomoxis nigro-maculatus, P. annularis)* were added along with bass and bluegills to increase the variety. In still others, such fishes as could be caught from nearby streams or ponds, such as many species of minnows, green sunfish, orange-spotted sunfish (*L. humilis*) longear sunfish, and warmouth (*Chaenobryttus coronarius*) were introduced. In two instances we found that the owners had introduced smallmouth buffalo (*Ictiobus bubalus*) and hoped to raise several hundred pounds of harvestable fish every year. Those ponds were fertilized heavily and the fish fed such items as crushed corn and wheat and tankage. When they were seined in the summer of 1949 the young-of-the-year buffalo were very thin and emaciated in appearance. In two other ponds the owners had introduced goldfish (*Carassius auratus*) and in one other, white perch (sheepshead or freshwater drum, *Aplodinotus grunniens*). Of those farmers who planted other kinds of fish in their ponds, by far the majority (16 cases) had selected black bullheads (*Ameiurus melas*). In most of those instances, one seine haul would yield hundreds of small black bullheads from 3 to 4 inches long. In four instances it was found that neighboring children had caught green sunfish from nearby streams and introduced them in the ponds.

In the six ponds from which we seined other kinds of fish but found no hybrids, owners had stocked the ponds prior to the introduction of the hybrids. Plantings of hybrids would not have been made had we known of the previous plantings since in all probability, they would disappear within a few years. Such disappearance would stem from a low reproductive potential and a consequent inability to maintain the population of hybrids. In checking, 11 more ponds were found that had been stocked with other species of fish prior to the planting of hybrids. From them were recovered a total of 45 hybrids of similar size to those recovered from the other ponds. These fish ranged from 100 to 176 millimeters, fork length and their weights were well within the range of weights for other fish of their respective lengths.

Apparently other hybrid sunfish will grow well, in any pond, providing the competition is not too great, as many crosses other than the bluegill x redear have been taken. One of the commonest is that between the bluegill and the green sunfish. Such hybrids are usually larger than other fish of the same year class of either of the parents.

ACKNOWLEDGMENTS

Many individuals have assisted in the project. Dr. W. E. Ricker, Director of the Indiana Lake and Stream Survey, having already inaugurated the program, gave valuable information and helped in collecting the parent stock and the distribution of the hybrid fingerlings. Messrs. M. M. Merritt, M. C. Ferguson, D. S. Bishop, Pat Deckard, Wm. Arganbright, Francis Post, and others of the U. S. Soil Conservation Service assisted in the selection of ponds, the planting of fish, and acted as "guides" when the ponds were seined. Messrs. W. T. Miller, Ned A. Bowman, Bill Schleicher, and David Farris and others assisted in seining operations and the collection of field data. Sincere appreciation is expressed to the owners of the ponds used in these experiments.

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FOURTEEN YEARS RECORD OF FISH PRODUCTION FROM MEANDER LAKE

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Abstract

Meander Lake is an artificial lake of 2,010 acres in which no angling is permitted, but from which the Ohio Division of Wildlife has removed fish by trap net annually.

The lake was filled in February, 1932 and was stocked in 1932, 1934, and 1935, with a total of approximately 10,000 adult fish (about 200 largemouth bass, 1,100 bluegills, 850 bullheads, 1,700 gizzard shad, and 6,000 crappies) and in the spring of 1940, with 400 breeder white bass.

Removal of fish by nets began in the fall of 1935. In 1938, nets were used both during the spring and fall and since 1939, only in the spring, prior to spawning. An average of 16 pounds of fish was removed from each acre annually. About 4 percent of these were largemouth bass, 5 percent bluegills, and 65 percent white crappies. Bass and bluegill removal averaged nearly 10 percent each of the total catch for the first 5 years, crappies increased rapidly to reach a peak in 1942. Since that year crappies have gradually decreased and in 1948, white bass constituted the major catch of the lake. Size of the various species varied through the years and in some cases appeared to be correlated with the number removed. Crappie decrease apparently was correlated with many factors such as spring harvest and drop in lake fertility, but the major factor appeared to be the development of several other species of fish.

Introduction

Public fishing is not permitted in Meander Lake but by agreement with the Mahoning Valley Sanitary District, the Ohio Division of Wildlife annually live traps fish which are then distributed to public fishing waters. Meander Lake was built by the Mahoning Valley Sanitary District in northeastern Ohio for domestic water supply. At spillway level it has a surface area of 2,010 acres and contains 32,473 acre feet of water. The average depth is 16.1 feet and the length of shoreline is equivalent to 106 feet per surface acre. The lake has a drainage area of 86.5 square miles of which the water surface occupies 3.5 percent. Thirty percent of the drainage area is wooded, 40 percent is in pasture, and 30 percent is cultivated. Practically all brush and land vegetation was cut and removed from the area to be flooded and only that which had grown between cutting and filling was present when the water was raised. No devices favorable to fish production were installed in the lake, nor was any measure taken to improve the lake from a fish management standpoint.

TABLE 1.—*Area, volume, level, turbidity, color, hydrogen-ion concentration and carbon dioxide, expressed as annual averages for the years 1932-1947.*

Year	Turbidity p.p.m.	CO_2 p.p.m.	pH	Color	Water Volume in Million Gallons	Water Area in Acres
1932	....	....	....	....	9,960	1,920
1933	10	1.5	7.6	18	9,630	1,880
1934	7	3.8	7.3	16	9,630	1,880
1935	7	3.3	7.5	18	10,380	1,980
1936	10	6.2	7.1	18	9,848	1,910
1937	19	5.0	7.2	25	10,260	1,970
1938	10.7	5.2	7.3	18	10,320	1,980
1939	14	1.9	7.3	21	9,795	1,885
1940	11.5	4.4	7.3	20	9,848	1,900
1941	8.0	3.7	7.4	17	9,848	1,900
1942	7	1.8	7.5	15	10,080	1,940
1943	10	2.3	7.4	17	9,960	1,920
1944	8	2.2	7.6	12	8,670	1,725
1945	10	2.6	7.6	14	9,290	1,820
1946	7	2.3	7.5	17	9,400	1,840
1947	10	2.3	7.6	17	9,568	1,860

PHYSICAL AND CHEMICAL CHARACTERISTICS

Daily and monthly observations of the physical and chemical quality of the lake water have been made by the Mahoning Valley Sanitary District since 1932 when the lake was filled (Table 1).[1] During the first 3 years the Ohio Division of Wildlife made additional tests of the water including those for dissolved oxygen, Secchi disc transparency, normal and bicarbonates, and counts for plankton and bottom organisms (Roach, 1933; Wickliff and Roach, 1937). These observations have shown considerable variation in water condition, but except as noted in the following paragraphs, none of them indicate trends that might have influenced fish production or populations.

Water temperatures rose consistently with aging of the lake. Successive 5-year average temperatures from 1933 were 10.6° C., 10.9° C., and 11.9° C. During these same periods turbidity was 10.6 p.p.m., 10.2 p.p.m., and 9.0 p.p.m. In succeeding periods free carbon dioxide dropped with 4.0 p.p.m., 3.0 p.p.m., 2.3 p.p.m., color with 19, 18, and 15, but pH rose with 7.34, 7.36, and 7.44.

During the 3 years that plankton samples and bottom organisms were enumerated, a definite decrease in plankton was noted each succeeding year from 1932 to 1934. During this period, however, bottom organisms increased. Copper sulphate was used in the lower lake annually between 1932 and 1935, but was discontinued after 1935 because no further algal "blooms" were noted. Rooted aquatic vegetation reached its maximum in 1948 when it covered an area of nearly 185 acres, the greater part of which was above the 5-foot contour.

Although spillway level is 905 feet above sea level, the average annual water stage for the first 16 years was 903.7 feet. This reduced the total surface area from 2,010 to an annual average of 1,890 acres (92 percent) and the total volume at spillway level of 10,560 million gallons to an annual average of 9,800 million gallons (91 percent). The use of water by the Sanitary District during dry seasons and exhaustion of oxygen below the thermocline in late summer further reduced the volume of productive water. On an average during the period covered by these data, the hypolimnion lay below the 20-foot level and made up 15 percent of the total volume. As a result of these reductions 35 percent of the volume of this lake was removed from fish production for relatively long periods each year.

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[1] These data were made available to us through the courtesy of Mr. L. T. Fawcett, Engineer and Secretary of the Mahoning Valley Sanitary District and Mr. Wm. I. Van Arnum, Chief Chemist for the District.

The water remained near spillway level during the spawning seasons (April, May, and June). In 1934 the level dropped more than 1 foot at this season, but in all the other years, except 1941, the level fell less than 6 inches. The most extensive drops occurred during September, October, November, December, and January. On January 13, 1945 the water level fell 9 feet below spillway level.

FISH STOCKED

The stocking history of Meander Lake has not been completely recorded. Fish live trapped from nearby Lake Rockwell were loaded on tank trucks and within an hour were placed in Meander. Fortunately, the men in charge of these netting operations are still in our employ and their memory as to the number of "loads" and the species involved is good, although the number of fish per load must be an estimate (Table 2). During this period 6,150 white crappies *(Pomoxis annularis)*, 850 brown bullheads *(Ameiurus nebulosis)*, 1,100 bluegills *(Lepomis macrochirus)*, 200 largemouth black bass *(Micropterus salmoides)*, 1,700 gizzard shad *(Dorosoma cepedianum)*, 400 white bass *(Lepibema chrysops)*, and approximately 100,000 blunt-nose minnows *(Hyborhynchus notatus)* were placed in the lake. In 1937, the dam of a small private pond in the headwaters of the drainage broke and some fish escaped into Meander. It is believed that this accident was the source of yellow perch *(Perca flavescens)*.

TABLE 2.—*Estimated number of fish stocked in Meander Lake, 1932-1940.*

Species	1932 April	1934 Spring	1934 Fall	1935 Fall	1940 Spring	1940 Fall	Total
White crappies	500	1,000	4,650				6,150
Bullheads	750		100				850
Bluegills			1,100				1,100
Largemouth black bass			200				200
Gizzard shad				1,700			1,700
White bass					400		400
Bluntnosed minnows						100,000	100,000
Total	1,250	1,000	6,050	1,700	400	100,000	110,400

TABLE 3.—*Annual fish production from Meander Lake for years 1935-1948. Yield expressed as percentage of total numbers and total weight by species.*

Year	Largemouth bass		Bluegills		White crappies		Bullheads		Yellow perch		White Bass		Gizzard Shad		Suckers	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
1935	0.04	0.2	2.0	2.0	88.0	68.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	25.0
1936	1.0	6.8	12.0	11.4	80.0	62.0	4.0	5.0	0.0	0.0	0.0	0.0	2.0	5.0	1.0	6.0
1937	1.0	8.5	5.5	5.0	82.0	64.0	9.0	16.0	0.0	0.0	0.0	0.0	1.3	1.0	1.0	5.0
1938	0.5	6.0	7.0	7.0	80.0	64.0	4.1	10.2	0.0	0.0	0.0	0.0	5.0	10.0	P	1.0
1939	1.0	10.8	2.5	2.0	76.0	59.0	3.0	6.0	P	P	0.0	0.0	17.0	19.0	P	1.0
1940	1.0	5.0	5.0	4.0	87.0	72.0	6.0	9.0	P	P	0.0	0.0	2.0	2.0	P	1.0
1941	0.2	1.0	6.0	3.0	89.0	90.0	2.0	2.0	P	P	0.0	0.0	3.0	3.0	P	1.0
1942	0.3	1.0	4.0	3.0	55.0	85.0	2.0	3.0	P	P	0.0	0.0	4.0	5.0	P	1.0
1943	1.0	3.0	8.0	4.0	78.0	78.0	4.0	4.0	4.0	2.0	P	P	2.0	2.0	1.0	2.0
1944	0.5	1.0	7.0	3.0	80.0	86.0	3.0	4.0	8.0	4.0	0.6	0.3	....	....	1.0	2.0
1945	0.7	1.0	9.0	4.0	77.0	83.0	1.0	2.0	10.0	6.0	0.6	0.8	....	....	1.0	2.0
1946	0.7	2.0	5.0	2.0	81.0	78.0	2.0	3.0	6.0	4.0	0.4	0.4	....	....	3.0	7.0
1947	2.0	6.0	14.0	6.0	51.0	48.0	3.0	3.0	3.0	2.0	13.0	7.0	....	....	5.0	15.0
1948	0.7	2.0	17.0	11.0	49.0	31.0	1.0	2.0	4.0	4.0	30.0	41.0	....	....	2.0	7.0
Average	0.76	4.0	7.4	4.7	75.0	65.0	3.0	4.6	2.5	1.6	3.2	3.6	2.7	3.6	2.0	5.0

ANNUAL FISH PRODUCTION

Netting crews of the Ohio Division of Wildlife began operating trap nets for the removal of fish in September, 1935, and continued fall netting through 1937. In 1938 fish were harvested both in the spring and in the fall; and from 1939 to the present all netting was done in April and May.[2]

All fish were weighed and counted by species at time of capture. Production ranged from a total of 203 fish weighing 34 pounds per acre in 1938 to 16 fish weighing 6 pounds per acre in 1948 (Table 3). The lake produced an annual average of nearly 61 fish weighing over 16 pounds per acre. Most of these (75 percent by number, 65 percent by weight) were white crappies. Bluegills greatly exceeded largemouth black bass in numbers (4.5 to 0.5 per acre), but very little in weight (0.8 to 0.7 pounds). Bullheads (mostly brown) ranged between the bluegills and bass in number (1.8 per acre), but practically equalled bluegills in weight. Other species occurred in considerable numbers at times. For example, suckers (mostly the golden redhorse—*Moxostoma erythrurum)* constituted a major portion of the production in early years, then was followed for a few years by gizzard shad. During the last 3 years, particularly in 1948, white bass production has been high.

It will be noted that fish harvest began only 3 years after an initial light stocking of crappies and bullheads and only 1 year after a final stocking of crappies, bluegills, bullheads, and largemouth bass. Three years after the only recorded stocking of gizzard shad (1935) their production reached a maximum. White bass were taken 3 years after very limited stocking and made up 30 percent of the total catch by 1948.

Peak production was reached in 1938, 6 years after completion of the lake and 3 years after harvest had begun. This peak was caused by the fact that netting operations were conducted both in the spring and fall. Although production in numbers decreased following 1938, another peak in weight occurred in 1942 with considerably less fishing effort. The greatest black bass harvest was made between 1936 and 1940, 2 years after the initial stocking. Bluegills and bass harvest by weight has remained relatively steady since 1940, but there has been a decrease in crappies since 1942.

SIZE DISTRIBUTION OF THE CATCH

For the first 5 years crappie harvest was made up of large numbers of relatively small fish (127,000 fish annually averaging 0.16 pounds, 7¼ inches, each). From 1940 to 1947, fewer, but larger crap-

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[2] Operations in 1935, 1936, and 1937 were under the direction of A. C. Downing, Fish Farm Foreman, Akron. Operations from 1938 to and including 1945 were under the direction of George D. Messerly now State Supervisor of Fish Farms. Operations since 1946 have been under the supervision of Roy McCracken, Fish Farm Foreman. Dan Armbruster, Fish Management Agent in District 3, assisted in compiling some of these data and mapped the vegetation in Meander Lake in 1948.

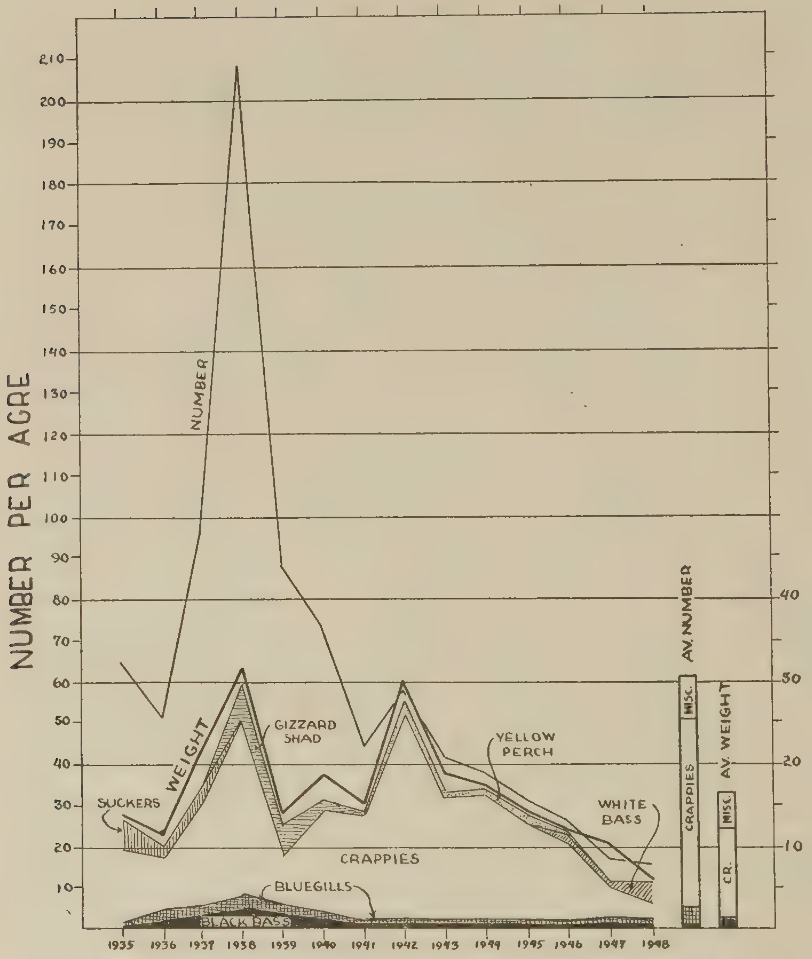

FIGURE 1.—Annual fish production (harvest) of Meander Lake from 1935 to 1948.

pies (59,000 annually at 0.46 pounds, 10 inches, each) were harvested. A similar pattern was followed by the bluegills. From 1936 to 1939 inclusive, an average of 11,000 fish each year with an average weight of 0.18 pounds and a length of 7 inches was harvested annually (Table 4).

The relation of size to total number of largemouth bass was somewhat erratic. Apparently size became greater as numbers increased during the first 2 or 3 years, but although numbers remained relatively high, the average weight fell off in 1938. During the following two

TABLE 4.—*Total number of major species produced in Meander Lake and average weight in pounds, 1936-1948.*

Year	Largemouth black bass		Bluegills		White crappies		Bullheads		White bass		Yellow perch		Carp		Gizzard shad	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
1936	973	1.5	12,378	0.20	80,558	0.17	3,872	0.23	......	......	......	......	......	......	2,524	0.23
1937	1,722	2.0	10,324	0.20	155,167	0.17	17,466	0.40	......	......	......	......	......	......	2,469	0.11
1938	1,716	0.8	16,872	0.16	141,645	0.12	4,635	0.30	......	......	......	......	......	......	3,852	0.29
1939	1,616	1.8	4,349	0.16	134,566	0.12	155	0.30	......	......	11	0.36	5	1.6	30,764	0.16
1940	1,350	1.5	6,950	0.20	126,369	0.21	8,299	0.31	......	......	421	0.26	226	0.4	2,427	0.21
1941	238	1.2	5,314	0.14	79,162	0.32	1,513	0.39	......	......	364	0.26	3	2.6	2,711	0.31
1942	508	1.3	7,045	0.24	98,840	0.51	4,043	0.47	......	......	217	0.29	141	2.4	6,325	0.46
1943	928	1.3	6,962	0.24	66,173	0.45	3,457	0.48	79	1.06	3,159	0.21	144	2.4	2,138	0.44
1944	339	1.4	5,399	0.20	61,287	0.50	2,640	0.49	478	0.23	6,182	0.23	18	3.8	......	......
1945	432	0.9	5,436	0.20	48,068	0.51	737	0.62	350	0.70	6,538	0.29	32	0.5	......	......
1946	368	1.7	2,704	0.22	42,154	0.47	70	1.10	226	0.42	3,136	0.27	112	3.3	......	......
1947	859	1.3	5,033	0.25	18,177	0.49	1,057	0.63	4,728	0.26	1,086	0.39	39	3.0	116	0.58
1948	210	1.4	5,499	0.24	12,924	0.25	382	0.55	9,870	0.50	1,363	0.32	59	2.3	......	......

years the trend continued, but after 1940 it leveled off. It is apparent that numbers and average size were much greater during the first 5 or 6 years than at any time since. From 1935 through 1940, an annual average of 1,495 largemouth bass weighing over 1.5 pounds each was harvested. Since 1940, only 484 fish weighing less than 1.3 pounds each have been harvested each year.

VARIATIONS IN FISH POPULATION SIZE

Inasmuch as from 8 to 18 trap nets were used annually for a period of 2 months during the same season each year (approximately 21,000 net hours except in 1935, 1936, and 1937) and because they have been operated in nearly every part of the lake, it is felt that an expression of the number of fish caught per net hour can be used as an index of the population size (Table 5).

TABLE 5.—*Annual fish production from Meander Lake, 1935-1948. Yield expressed as numbers and pounds per acre and per trap-net hour.*

Year	Total catch per acre		Total catch per trap-net hour	
	Number	Weight	Number	Weight
1935	65	14	5	1
1936	50	10	4	1
1937	94	21	7	2
1938	203	34	17	3
1939	88	13	11	2
1940	73	19	10	3
1941	45	14	6	2
1942	59	29	8	4
1943	42	19	6	3
1944	38	18	5	2
1945	31	15	4	2
1946	26	13	4	2
1947	17	9	3	2
1948	16	6	3	1
Average	61	17	7	2

The first measure of the fish population in Meander Lake was made in 1935, 3 years after its formation. At this time five fish with a weight of 1 pound were taken per hour. Eighty-eight percent of this catch were crappies (68 percent by weight) and eight percent were suckers (25 percent by weight). In 1936 only four fish with a weight of 0.8 pounds were taken per net hour. Sucker catch dropped to 1 percent (6 percent by weight) and crappie catch to 80 percent (62 percent by weight). However, bluegill catch increased five times in number and bass increased nearly 20 times in number.

The total population of fish and all major species except largemouth bass continued to increase after 1936 and reached a peak in 1938. Bass reached their peak in 1940. Following 1938, a general decrease in the total population (except for a small interruption in 1942) was noted. For the most part the total was influenced by the crappies, although bullheads, with some irregularity, followed the same pattern. The bluegill and largemouth bass populations have shown a remarkably static condition since 1938 and 1940, respectively.

The weight of the fish population followed a different pattern. The greatest poundage was not reached until 1942, 10 years after the lake was flooded and 8 years following the final stocking. This peak was caused primarily by crappies. In 1938 and in 1940 smaller peaks occurred which reflected poundages of bluegills, largemouth bass, bullheads, and gizzard shad. Following 1942, there was a general decrease in total poundage.

From available data it appears that there was a rapid increase in fish numbers up to the sixth year after formation of the lake and then a gradual decrease. The peak weight of the population was reached at 10 years after a gradual rise. It then declined more rapidly to its present level. In 1948 the population showed a slight numerical increase, but no increase in weight. Except in a very few instances the number and weight curves bear a striking correlation.

Shoemaker (1944) reported an aquarium study on guppies *(Lebistes reticulatus)* in which this species produced a population picture very similar to that of the crappies in Meander. The number and weight of bluegills varies almost directly except in 1942 when decreasing numbers showed an increase in weight. The largemouth bass increased in number and weight from 1935 to 1939, then decreased in 1941 and in 1945, and again reached a peak in 1943 and 1947.

Seventeen hundred gizzard shad were stocked in 1935, but were negligible elements in the population until 1938 when they comprised 5 percent of the total number and 10 percent of the total weight. More than 28,000 shad averaging over one-quarter pound each were removed during 1938. In 1939 the 30,000 fish removed constituted 17 percent by number and 19 percent by weight of the total population. Between 1939 and 1943 shad made up only 2 to 4 percent of the total population, but after 1943 none were taken in the nets.

Of the 400 white bass stocked in 1940 it is estimated that approximately half were dead on arrival or died shortly after. A few were taken in 1943, but through 1946 they made up less than 1 percent of the population by number and weight. In 1947 they made up 13 percent of the total population in numbers and 7 percent in weight. By 1948 they made up 30 percent in numbers and outranked all other fish in weight with 41 percent of the total population.

Growth Rates and Length Distribution

In 1938, over 85 percent of the white crappies, above the size retained by our nets, ranged between 6 and 8 inches in length and none was taken over 9 inches (Table 6). All were in their second and third summers in life. In 1946, they ranged from 7½ inches to 14½ inches

TABLE 6.—*Length distribution of three major species of fish in Meander Lake, 1938-1948. Expressed as percentage of total number.*

Length Interval	Largemouth Bass				White Crappies				Bluegills			
	May 1938	Sept. 1938	May 1946	May 1948	May 1938	Sept. 1938	May 1946	May 1948	May 1938	Sept. 1938	May 1946	May 1948
4	......	......	......	......	......	......	......	......	......	P	2	7
4½	......	......	......	......	......	......	......	......	10	2	7	6
5	......	......	......	......	2	1	......	4	27	7	16	9
5½	......	......	......	......	8	......	1	1	16	15	10	7
6	......	......	......	......	5	5	1	1	18	18	15	7
6½	......	......	......	......	30	10	......	2	20	30	12	8
7	......	......	......	......	24	33	......	9	7	19	8	26
7½	6	......	......	......	20	20	......	14	2	9	13	24
8	6	3	......	......	7	6	4	18	......	......	11	6
8½	3	......	......	......	2	5	6	14	......	......	6	......
9	10	......	......	......	2	5	4	7	......	......	......	......
9½	5	10	......	......	......	6	4	6	......	......	......	......
10	5	11	......	......	......	4	11	6	......	......	......	......
10½	3	12	......	......	......	2	7	4	......	......	......	......
11	2	8	......	8	......	......	12	2	......	......	......	......
11½	8	12	......	17	......	......	9	2	......	......	......	......
12	5	11	......	8	......	2	17	4	......	......	......	......
12½	10	3	......	8	......	1	9	4	......	......	......	......
13	......	6	12	13	......	......	4	2	......	......	......	......
13½	5	......	......	......	......	......	4	1	......	......	......	......
14	5	6	25	8	......	......	4	......	......	......	......	......
14½	......	8	13	22	......	......	1	P	......	......	......	......
15	......	......	25	12	......	......	1	......	......	......	......	......
15½	2	5	......	......	......	......	......	......	......	......	......	......
16	6	......	13	......	......	......	......	......	......	......	......	......
16½	5	2	......	......	......	......	......	......	......	......	......	......
17	3	......	12	4	......	......	......	......	......	......	......	......
17½	3	......	......	......	......	......	......	......	......	......	......	......
18	6	......	......	......	......	......	......	......	......	......	......	......
18½	......	2	......	......	......	......	......	......	......	......	......	......
19	2	......	......	......	......	......	......	......	......	......	......	......
Total	63	64	8	24	136	108	382	243	164	154	296	148

in length with 70 percent between 10 and 13 inches. The majority of these fish were in their fourth summer of life. In 1948, the size of this species ranged from 5 inches to 13½ inches in length with 60 percent between 7 and 9 inches in their second year. In 1948, Meander Lake white crappies measured nearly 2 inches longer at each annulus than a state average arrived at from fish from 53 different bodies of water. (Roach and Evans, 1948.)

Bluegills in 1938 ranged between 4½ and 7½ inches in length with over 75 percent between 5 and 6½ inches in length. This group represented fish in their second and third summers. In 1946, bluegills ranged between 4 and 8½ inches in length with a fairly even distribution at each half inch frequency between these extremes. In 1948, the range was practically the same, but nearly 65 percent were between 6½ and 8 inches in length. Growth determinations made in 1947 indicated that 4-inch bluegills were in their third summer, 6-inch bluegills were in their fifth summer, and 8-inch bluegills were in their seventh summer. Bluegills' growth in this deep lake does not seem to be very rapid. In fact, based on a state average growth of bluegills from 65 different Ohio lakes, Meander Lake bluegills averaged somewhat shorter in length at each annulus. It is apparent that while the lake was still comparatively young (1938) bluegill growth was quite rapid.

Length distribution of largemouth black bass in Meander Lake in 1938, ranged from 8 to 19 inches. The distribution was irregular, but was spread fairly evenly. Unfortunately, no growth rate studies were made on bass during this period. In 1946, largemouth bass ranged from 12½ to 17½ inches in length with nearly 65 percent between 14 and 15 inches in length. According to 1947 scale-age determinations, these fish would be in their fifth summer. In 1948, this species ranged from 11 to 15½ inches in length (fourth summer). Almost all the others were in their fifth summer. Largemouth bass in this lake ranged only slightly longer per given age than do the average from 44 Ohio lakes.

SUMMARY

On recapitulating the events making up the history of Meander Lake the following facts appear most significant:

There was apparently an annual decrease in basic fertility which was indicated by a decrease of free carbon dioxide, color, turbidity, and plankton organisms. These changes were most noticeable since 1940. Average annual water area and water volume have been consistently less since 1942. Beginning in 1938, the fish harvest dates were changed from autumn to spring and annual harvests since 1938 were mostly completed prior to spawning. All species of fish that began with the new lake had relatively high populations until approximately 1940. Since that year the largemouth bass, bluegills, and bullheads have varied around a lower mean. Gizzard shad reached a peak in 1939 and thereafter steadily declined until they disappeared in 1944. Yellow perch constituted a measurable component of the total population beginning in 1943. White bass were planted in 1940, but did not constitute a measurable part of the total population until 1943, and were not a major part of it until 1946. Suckers (native stream species) were numerous in 1935, decreased to practically nothing by 1938, but reappeared in 1946 and made up a sizeable part of the population through 1948. Crappies reached their population peak in 1938 (by numbers) and 1942 (by weight), but have declined steadily ever since.

Apparently a number of events climaxed between 1938 and 1942 which reacted most noticeably in extreme reduction of the gizzard shad and crappie population and less noticeable among the other species. The variations in fertility, water level, and water volume and their accom-
all fish or at least not so extremely unfavorable on one or two species.

The shift from autumn to spring harvest would lead one to the same assumption unless the exploitation of the two species was greater in
panying factors could be assumed to react in a comparable manner on
proportion than for the others, which does not seem to be true. To refute the feeling that spring harvest caused the direct decrease in giz-

zard shad and crappies, it will be recalled that spring harvest was inaugurated on a much greater population than the 1935 autumn harvest and neither numbers (nor pounds) were removed in as high a proportion to the 1938 population as were in 1935.

The decrease in crappies and gizzard shad seemed to be more directly correlated with the development of the populations of several other species. Suckers dropped to a low within 5 years after the lake was filled and were nearly non-existent 2 years later, but made a recovery in 1943, 12 years after the lake filled and constituted a sizeable percentage of the population in the last 3 years. This late return of suckers coincided with a drop in crappie population and a rise in the yellow perch population and to some extent the rise in white bass, although the latter reached its highest point in 1948, while the perch population dropped somewhat in 1946, 1947, and 1948.

Coincidental with the rise in these species (yellow perch beginning in 1942, suckers beginning in 1943, and white bass beginning in 1943), there was a decrease in gizzard shad (beginning in 1940 and disappearing completely in 1944) and white crappies (most rapid drop between 1940 and 1941).

One fact that all these changes seem to point to is the rise in white bass. White bass were stocked in 1940, but apparently 3 years passed before they multiplied sufficiently to constitute a measurable part of the population. Nevertheless, while in this early period of building up numbers and age, their feeding habits and their relationship was felt. Thus, it appears that the addition of white bass to Meander Lake was the final weight that tipped the scales.

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MENHADEN UTILIZATION IN RELATION TO THE CONSERVATION OF FOOD AND GAME FISHES OF THE TEXAS GULF COAST

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Abstract

Purse seining for menhaden off the Texas Gulf coast is unlawful because it is believed that such seining would take large numbers of game and food fish and reduce the forage-fish population.

Out of 2,500,000 menhaden taken in 17 purse-seine hauls in Louisiana waters over a 2-month period, 208 game and food fish comprising 12 species were caught. Stomach analyses were made on 5,946 fish of 34 species caught June 7 to August 31, 1948. They represented all the important game and food fish on the Texas coast. Menhaden were found in 165 stomachs with a frequency of 2.8 percent. Only 11 of the 34 species had eaten menhaden and in these the frequency of occurrence never exceeded 10.0 percent. The frequency of food items in the diet of these fishes was shrimp 61.8 percent, fishes exclusive of the menhaden 34.2 percent, crabs 12.0 percent, squids 4.0 percent, and miscellaneous invertebrates 4.4 percent. Menhaden and mullets appear to be the most used species of forage fish, but since these fishes are identified by their gizzard-like stomachs after all other structures have been digested, this high occurrence may be more apparent than real. The menhaden fishing industry catches only the Gulf menhaden *(Brevoortia patronus)* which seldom enters the bay areas. The bay menhaden *(B. gunteri)* rarely enters the open Gulf since it lives in areas of low salinity. Therefore, a menhaden fishing industry should not interfere with sport or commercial fishing in the bays. Actually, such a fishery may be beneficial by its reduction of sharks and other undesirable fishes in the area.

Introduction

At the present time (August, 1949) fishing for menhaden by means of purse seines is unlawful in Texas waters. The menhaden fishermen claim that the catching of this fish by purse seining does not interfere with, nor have any noticeable effect on, sport or other commercial fishing. They also maintain that it is wasteful to allow millions of menhaden to die each year without any attempt to utilize them. Not only does this deprive men of jobs, but it deprives the farmer and the manufacturer of needed protein stock meal and oil. They are supported in this view by feed companies which must import fish-meal from other states at a much higher cost than it could be produced locally. On the other hand both sport and commercial fishermen claim that purse seines have a harmful effect on other fishing by: (1) catching many game and food fish along with the menhaden, and (2) reducing the food supply for other fish by reducing the population of menhaden.

The present investigation was initiated by the Game, Fish and Oyster Commission of Texas to obtain information on these problems. Field work was carried on from June 7 to August 31, 1948. During this time three lines of investigation were followed. The menhaden fishery at Port Arthur was analyzed to determine the volume of menhaden caught and the number of game and food fish captured with them in the purse seines. The food habits of the game and food fish were studied to determine to what extent they feed upon menhaden. Observations were also made on the distribution and abundance of the menhaden.

The Texas coast is characterized by a series of long, narrow islands situated several miles off shore and lying parallel to the mainland. Between these islands and the mainland are large shallow bays, the salinities of which are usually much lower than the open waters of the Gulf because fresh water flows into them. In drought years, however, these bays may have salinities equal to, or greater than those of the Gulf. Such differential salinities are made possible by the relatively few channels which connect the open Gulf water with the bays. These channels are considered excellent for sport fishing since they afford the only passageways for fishes moving between the bays and the Gulf.

Four stations were established for the collection of fish. These were: (1) At Galveston where Gulf fishes were obtained from beach seiners, party boat operators, and commercial fishermen. (2) At Cedar Bayou where bay fishes were obtained by fyke netting. Since this is the only open channel between the Gulf and the bays in a 40-mile stretch, both Gulf and bay fishes were expected in the catches. However, the catch consisted almost entirely of bay fishes. (3) At Rockport where bay fishes were obtained from charter boat operators. (4) At Port Aransas where Gulf fishes were taken with beach seines and party boats.

In addition to the stations established for the collection of fish stomachs, an observer was stationed on the menhaden steamer, "H. C. Dashiell," from June 14 to August 14 to keep a record of the number of fish other than menhaden caught in the purse seine. This ship worked out of the menhaden plant at Sabine, Texas, and fished in Louisiana waters. The author also spent 1 week per month seining Aransas, Copano, and Mesquite Bays and made airplane flights over the Gulf to determine the relative abundance and distribution of the menhaden.

COMPOSITION OF PURSE-SEINE HAULS

The numbers and species of fish caught in 17 purse-seine hauls by the menhaden boat, "H.C. Dashiell," from June 14 to August 14, 1948 in Louisiana waters just east of the Texas boundary, were carefully enumerated (Table 1). During the period under consideration purse seining took very few game and food fishes. One successful day's catch by

Table 1.—*Number and length of fishes caught in 17 seine hauls from menhaden boat, June 14 to August 14, 1948.*

Kind of fish	Number	Standard length or diameter[1] inches
Brevoortia patronus	2,500,000	7–12
Sharks	63	14–18
Dasyatis sabina	12	5–14
Stoasodon narinari	1	16
Clupeoidei (approx.)	1,250	5–15
Megalops atlanticus	5	34–70
Bagre marina	3	6–18
Cynoscion sp	77	6–11
Cynoscion nebulosus	2	12
Sciaenops ocellatus	1	8
Leiostomus xanthurus	50	4–10
Pogonias cromis	3	6– 8
Menticirrhus sp	7	8–14
Scomberomorus maculatus	47	9–32
Pomatomus saltatrix	42	6–16
Trachinotus carolinus	8	8–13
Paralichthys lethostigmus	3	3–15

[1] *Dasyatis sabina, Stoasodon narinari.*

hook and line from two party boats would exceed the number of game and food fish caught by the purse seine in 2 months. It is also possible that menhaden fishing may be an asset to sport fishing by reducing the number of sharks in the area.

The 1,574 fish, other than menhaden caught in the 17 hauls, constituted 0.06 percent of the total catch. This percentage is less than the maximum of 1 percent allowed by many states having active menhaden fisheries. Smith (1896) recorded 94,795 other fish caught with 18,706,800 menhaden in purse seines from three boats ranging from Maine to North Carolina, May 7 to December 3, 1894. The percentage of other fish to menhaden calculated from Smith's results is 0.6, or 10 times that caught in the present study. In the observed Texas lifts (Table 1) the only desirable fish of sufficient size to feed on the menhaden are the Spanish mackerel *(Scomberomorus maculatus)*, bluefish *(Pomatomus saltatrix)* and tarpon *(Megalops atlanticus)*.

FOOD OF TEXAS COAST FISHES

Occurrence of Food Organisms.—A total of 10,016 fish comprising 34 food and game species were examined at the four collecting stations (Table 2). They represented approximately 20 percent of the total catch brought into these stations. Of the total number of fish examined 5,946 contained food. Shrimp (*Penaeus aztecus,* principally), which occurred in 61.8 percent of the stomachs, was the most widely used food. Fish other than menhaden with an occurrence of 34.2 percent were second in importance. Crabs with 12 percent, miscellaneous invertebrates (other than shrimp, crabs and squid) with 4.4 percent, squid with 4.0 percent, and menhaden with 2.8 percent occurrence followed in that order. This pattern is altered at Galveston and Port Aransas where

TABLE 2.—*Frequency of occurrence of food organisms in fish analyzed at four stations on the Texas coast, June 7 to August 31, 1948, expressed as numbers of fish and percentage of total fish containing each item.*

Item	Station				Total	Frequency as percent
	Galveston	Cedar Bayou	Rockport	Port Aransas		
Species examined	19	20	7	26	34	....
Fish examined	3,600	1,747	2,598	2,071	10,016	....
Fish with food	1,862	1,130	1,844	1,100	5,946	....
Shrimp	1,134	791	1,367	388	3,680	61.8
Miscellaneous Fish	528	334	596	581	2,039	34.2
Crabs	348	63	177	126	714	12.0
Miscellaneous Invertebrates	59	19	72	99	249	4.4
Squid	135	10	11	82	238	4.0
Menhaden	22	22	84	37	165	2.8

squid exceed the miscellaneous invertebrates and at Port Aransas where fish other than menhaden exceed the shrimp. These discrepancies may be caused by the fact that large numbers of spanish mackerel *(Scomberomorus maculatus)* which feed largely on other fish and kingfish *(S. cavalla)* which feed largely on squid were taken at these stations.

Since the importance of an organism in terms of food value involves both the number and volume which may be present in the fish's stomach, it is not possible to say with finality from frequency data that one food organism is more important than another. Nevertheless, the relative importance of the various items is probably well expressed in the percentage indicated above.

Many species of forage fish besides the menhaden provide food for other fish. The extent to which these are utilized may be seen in Table 3 in which the data obtained at the four stations have been combined. Thirty-one species have been omitted also because their frequency of occurrence was less than 0.2 percent, and their ecological significance was believed to be very small. Menhaden are the most important identified forage fish, although they comprise only a small part of the total diet of the game and food fishes. The mullets are next in order with the remaining species all occurring in only 1.5 percent of the stomachs or less. The large amount of unidentified fish remains constitute approximately 60 percent of all fishes found in the stomachs analyzed. These fish were too far digested to identify. It may be assumed, however, that these fish occurred in the same ratio as those that were identified with the exception of the menhaden and the mullet. In these latter fishes the stomachs are developed into a gizzard-like organ which resists digestion long after all other structures have disappeared. This fact should be taken into account in interpreting the high frequency of the menhaden and the mullets as compared to that of the other fish. It is to be noted that, among these forage fish, the flounder, a prized fish itself, is frequently eaten by other game and commercial species.

TABLE 3.—*Occurrence of fish in stomachs of 5,946 game and food fish from the Texas coast, June 7 to August 31, 1948, frequency expressed as number of fish and percentage of total fish.*

Kind of Forage Fish	Common Name	Number	Percentage
Unidentified fish		1,329	22.4
Brevoortia sp	menhaden	165	2.8
Mugil sp	mullets	114	1.9
Micropogon undulatus	croaker	87	1.5
Harengula pensacolae	sardine	64	1.1
Trichiurus lepturus	cutlass fish	59	1.0
Anchoa mitchelli	anchovy	56	0.9
Membras vagrans	rough silversides	49	0.8
Paralichthys lethostigmus	flounder	45	0.8
Orthopristis chrysopteris	piggy	32	0.5
Pleuronectidae	unidentified flat fishes	32	0.5
Etropus sp	fringe flounder	18	0.3
Leiostomus xanthurus	spot	13	0.2
Unidentified Clupeoidei	herring-like fishes	13	0.2

FOOD HABITS OF INDIVIDUAL SPECIES

The food preference of 34 species of game and food fish was observed, but only the 18 species which eat menhaden or were represented by an adequate sample are discussed here (Table 4). Menhaden did not form the primary or secondary food supply for any of the fishes studied and shared only third place with the shrimp and miscellaneous invertebrates in the food of tarpon and flounder respectively. Menhaden are fourth in importance in four species of fish *(Carcharhinus* sp., *Galeichthys felis, Scomberomorus cavalla* and *Istiophorus nigricans);* fifth place in four species *(Bagre marina, Sciaenops ocellatus, Cynoscion nebulosus* and *Scomberomorus maculatus);* and sixth place in one *(Menticirrhus* sp.*)*. Eleven species feed on the menhaden and in none of these does it exceed a frequency of 10.0 percent.

Shrimps are the main item of food for 11 species, second for 4 species and third for 2 species. Crabs are the main item of food for 2 species, second for 2 species, third for 10 species and fourth for 1 species. Fish other than menhaden are the staple diet for 5 species, second for 11 species and third for 2. Miscellaneous invertebrates are first in none, are second in only the cobia *(Rachycentron canadus)* and third in the flounder *(Paralichthys lethostigmus)*. Squids are not a primary or secondary food supply for any fish studied.

It should be noted that these observations cover a period of only 3 months and therefore may not be truly representative.

DISTRIBUTION AND ABUNDANCE OF THE MENHADEN

According to Hildebrand (1948) there are two species of menhaden present in Texas water. *Brevoortia patronus* Goode is called the large scale Gulf menhaden and is found more often in the open gulf waters than in the bay areas. This distribution has been shown by Gunter

TABLE 4.—*Food of 18 species of game and food fish of the Texas Coast, expressed as the percentage of occurrence in the total number of fish analyzed of each species, June 7 to August 31, 1948.*

Species	Number fish taken	Number stomachs analyzed	Food item					
			Crabs	Shrimp	Squid	Menhaden	Other fish	Other invertebrates
Carcharhinus sp.	232	126	9.5	33.3	9.5	9.5	62.0	0.8
Elops saurus	221	156	2.5	75.7	1.9	....	34.0	0.6
Megalops atlanticus	67	37	81.2	5.4	....	5.4	16.2	2.7
Bagre marina	375	225	16.0	54.2	1.8	1.3	40.4	4.9
Galeichthys felis	637	468	6.4	87.3	0.6	1.3	13.5	0.2
Rachycentron canadus	27	22	50.0	50.0	13.7	....	95.5	59.1
Caranx hippos	28	13	61.5	7.7	23.1	....	15.4	....
Lutianus blackfordi	136	46	26.1	34.8	17.4	....	19.6	6.5
Coryphaena hippurus	132	87	9.2	79.4	5.7	....	18.4	4.6
Sciaenops ocellatus	1,146	754	43.0	63.5	0.1	0.1	18.7	0.3
Menticirrhus sp.	410	259	10.4	54.4	5.4	0.8	38.3	6.9
Cynoscion nebulosus	4,439	2,698	6.0	69.9	1.0	3.4	33.3	3.7
Cynoscion sp.	204	90	11.1	72.3	2.2	....	21.1	4.4
Scomberomorus maculatus	1,174	458	4.6	23.4	10.9	3.7	62.7	2.4
Scomberomorus cavalla	541	327	0.6	43.5	25.1	7.9	42.7	0.9
Istiophorus nigricans	22	22	18.2	36.4	9.1	9.1	100.0	....
Paralichthys lethostigmus	41	24	....	50.0	....	4.2	41.7	4.2
Pomatomus saltatrix	12	12	....	66.6	58.5	....	80.0	....

(1945) to be caused by the low salinities of the bays in normal years, since this species is restricted to salinities higher than 25 p.p. thousand. *Brevoortia gunteri* Hildebrand is the fine scale Gulf menhaden or Bay menhaden. It is able to tolerate the very low salinities of the upper bays.

During this investigation, a survey was made of the menhaden population in Aransas, Copano, and Mesquite bays. Both species were found to be abundant throughout these areas. These observations do not conflict with Gunter's conclusion because the 1948 season was so dry that at no time during the investigation did the salinities in the bays fall below 26.3 p.p. thousand.

A 900-foot beach seine with a 1.25-inch mesh (stretch measure) was used to sample the fish populations. Menhaden from 3 to 11 inches total length were obtained in every haul. Many spotted squeteague, channel bass, and bigeye herring *(Elops saurus)* were caught in hauls along with the menhaden, but throughout the entire summer menhaden were found in the stomachs of only three spotted squeteague, one channel bass, and in no bigeye herring. These hauls indicate that the menhaden are much more abundant than the stomach contents of the various game and food fish would imply. Why they are not utilized as food to a greater extent is not known.

That menhaden are abundant in the Gulf is indicated by the fact that the menhaden steamer, "H. C. Dashiell," caught 2,500,000 menhaden in 17 hauls in a 2-month period from June 14 to August 14, 1948. Samples from these hauls did not yield any specimens of the bay menhaden *(B. gunteri)*. Therefore, in the region being fished by the steamer, it may be concluded that large schools of bay menhaden were not common. Since, according to Gunter (1945), the bay menhaden probably spawn in the back bays, it is probable that they spend most of their life in the bays. If this is so, the menhaden fishing boats, which operate only in the open waters of the Gulf, should not interfere with any bay fishery.

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FOOD OF THE BLACK CRAPPIE *POMOXIS NIGRO-MACULATUS* (LeSueur), IN ORANGE LAKE, FLORIDA

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Abstract

Orange Lake in north central Florida has an area of approximately 14,000 acres and is surrounded by extensive marshes. During a 12-month period, stomach contents of 902 black crappie *(Pomoxis nigro-maculatus)* ranging in size from 31 to 291 millimeters, standard length, were analyzed. The frequency of occurrence of various food organisms, seasonal trends in the consumption of food items, and the average volume of food per stomach are presented.

Gizzard shad are the most important food item of the adult crappie except during the spring months of February, March, and April when their frequency is exceeded or equalled by Malacostraca. In summer and fall crappies feed largely upon fishes and, to a lesser extent, upon Malacostraca, dipterous larvae, pupae and adults, and Entomostraca. During the winter months fishes constitute the main food of the crappie, all other food items occurring in less than 50 percent of the stomachs. The chief food of young crappies is Entomostraca. The consumption of larger organisms increases as they attain larger size. During breeding season male crappies eat approximately 33 percent more malacostracans and 33 percent less fish than females.

Introduction

Widespread interest in the black crappie, *Pomoxis nigro-maculatus,* and the scarcity of published ecological information concerning this species in Florida waters, suggested the study of the seasonal food habits which was carried on at Orange Lake from June, 1947 through May, 1948. Most of this lake is in Alachua County, Florida, and it is the largest of several bodies of water lying in a drainage basin of approximately 600 square miles. The surrounding terrain is gently rolling and pitted, particularly to the south, by numerous sinkholes in limestone formations which underlie the sandy topsoils.

The overall length is approximately 16 miles, the maximum width is nearly 4 miles, and the open water area covers approximately 14,000 acres. Maximum depth is approximately 35 feet. The bottom is composed of thick layers of silt and plant detritus over sandy clay and limestone. During 1948, the pH range was 6.8-7.2 except in June when the water level was lowest and the pH was then 8.2. During the same year the surface temperature varied from 33.0° C. in June, to 13.5° C. in January. Orange Lake water is usually turbid and colored brownish or greenish by large amounts of suspended detritus and its extractives and the presence of considerable quantities of plankton.

The lake is surrounded by extensive marshy areas which are dominated by *Nymphaea macrophylla, Sagittaria lancifolia, Pontederia lanceolata,* and several species of shrubs. The shallow waters of the littoral zone are dominated by *Ceratophyllum demersum* and *Naias guadalupensis.* A conspicuous part of the vegetation is formed by the large floating mats of *Piaropus crassipes.* Floating islands, varying in size from a few square feet to several acres, are found in Orange Lake. They are characterized by one or more of such emergent plants as *Sagittaria lancifolia, Mariscus jamaicensis, Persicaria* sp., and *Sambucus simpsonii.*

This lake produces and supports a rich fish population composed of approximately 30 identified species. Small species and forage fishes are quite abundant and thousands of sunfishes are taken annually by sport fishermen.

Seven collecting stations were established in areas which appeared to be typical or important environments in order to ascertain the relative abundance of crappies and other fishes in various situations. Collections were made at four of the stations by trapping and by pole fishing with live fishes for bait. The three remaining stations were shallow areas where a seine could be employed. One 10-foot common sense seine and one 20-foot bag seine with one-quarter-inch mesh were used. Dipnets were used under floating islands and in the marshy areas of the lake. Small specimens were also taken with a 6-foot cast net. Frequently catches of sport fishermen were examined and crappie stomachs taken.

FOOD OF THE BLACK CRAPPIE

Considerable information concerning food and feeding habits of the crappie has been gathered in previous studies. Crappie from the region of Illinois and Wisconsin were found by Forbes (1878), Forbes and Richardson (1920), and Pearse (1919) to have eaten mostly larvae and pupae of dipterous insects, cladocerans, amphipods, and ephemerid nymphs. Bailey and Harrison (1945) found the food of crappie in Iowa to consist of *Hyalella,* insects, and organic debris and fragments. Dendy (1946) found the food of adult crappie in Norris Reservoir, Tennessee, throughout the year to be mainly chaoborines and chironomids, plankton, and fishes.

In presenting the data concerning food and feeding habits of the crappie in Orange Lake the fish have been divided into two groups based on a natural break in the types of food organisms ingested as the crappie grew in size. A conspicuous decrease in the consumption of Entomostraca and an increase in utilization of larger food items were noted as the crappie reached approximately 100 millimeters in length. Consequently those individuals of less than 100 millimeters, standard length, are here classed as young while those of more than 100 millimeters are

TABLE 1.—*Crappie stomachs examined during period of June, 1947 through May, 1948.*

Month	Number examined	Number containing food	Number empty
June	45	36	9
July	65	43	22
August	103	72	31
September	74	52	22
October	82	65	17
November	74	67	7
December	49	40	9
January	93	79	14
February	76	75	1
March	77	68	9
April	91	72	19
May	73	71	2
Totals	902	740	162

termed adults. Further justification for this designation is also to be found in the conditions of gonads during breeding season.

A total of 902 stomachs which were collected over a 12-month period was examined during the investigation (Table 1). Of this group 740 stomachs contained food and 162 were empty. Only those stomachs which contained food were considered in the tabulations of food items.

Fishes.—Fishes were found in 66 percent of the stomachs examined and proved to be the most frequently taken food item of the adult crappie. Seventy-four percent of the adult stomachs and approximately 9.4 percent of young stomachs contained fishes (Fig. 1). Seventy-one percent of the fishes taken as food were identified as shad. Two species of clupeids are known to occur in Orange Lake; the gizzard shad *(Dorosoma cepedianum)* and the Florida lesser shad *(Signalosa petenensis vanhyningi)*.

As Hubbs (1934) suggests, the ecological role of the shad appears to be that of a connecting link between plankton and the larger piscivorous fishes. Insofar as the crappie is concerned, the plankton-shad-piscivorous fish chain is doubtless the most important food chain in the lake. Apparently the large population of crappies and Florida largemouth bass that characterizes the lake depends in a large measure upon the presence of these forage fishes.

Other identifiable fishes constituted only 1 percent of the total fishes taken as food by crappie. Represented by one or only a few individuals were: *Labidesthes sicculus vanhyningi,* an immature centrarchid, *Elassoma* sp., *Fundulus chrysotus, Gambusia affinis holbrooki,* and *Ameiurus nebulosus marmoratus.*

Young crappie apparently did not take fish for food until they reached a size of approximately 61 millimeters in length. From that size on, however, fishes were eaten with increasing frequency.

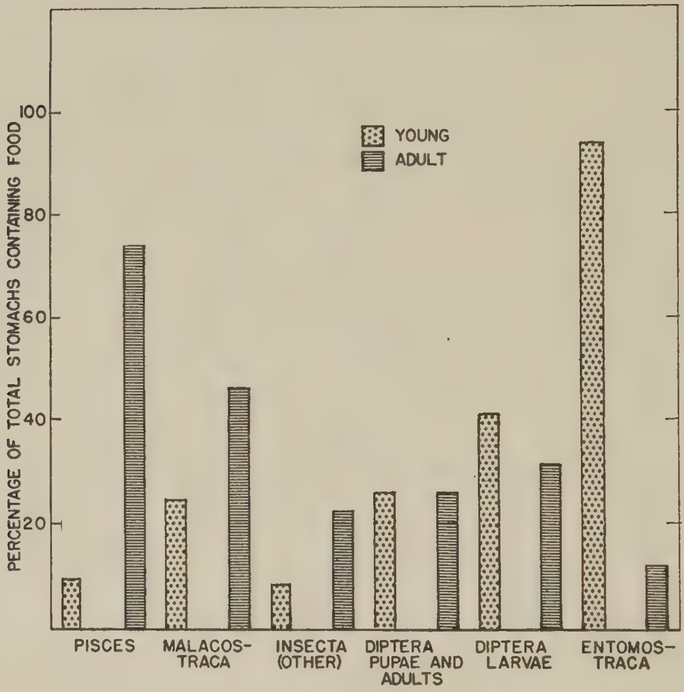

FIGURE 1.—*Diet in young and adult crappie based on frequency of occurrence of food groups.*

The consumption of fishes by crappie appeared to vary seasonally. In the months of May and June and those from October through January, nearly 90 percent of the adult crappies examined had eaten fishes. During the remaining months approximately 65 percent of the stomachs contained fishes. During the summer months (July-September) 17 percent of the stomachs of young crappie contained fishes, but only 8 percent of the young crappies examined had eaten fishes during May and June.

Amphibia.—Amphibians as a group formed an insignificant item in the food of crappie. One frog, *Hyla* sp., was found in a stomach in February, 1948. Several larval salamanders *(Pseudobranchus striatus axanthus)* were taken by one crappie in April, 1947.

Insecta.—Insects comprised the most frequently taken food item although the kinds varied seasonally. One or more kinds of insects occurred in over 80 percent of the stomachs examined.

Dipterous pupae and adults occurred in 27 percent of the stomachs examined. The most common forms were *Chaoborus* sp. and chironomids. Pupae and adults of these Diptera were taken by both young and adult crappies throughout the year and constituted 52 percent of the total number of Diptera consumed.

Dipterous larvae of the kinds previously mentioned occurred in 33.6 percent of all the crappie stomachs, having been found in 41 percent of young individuals and 32.6 percent of the adults.

Insects other than Diptera were found in 21.3 percent of the stomachs examined. Of the total number of non-dipterous insects which occurred in these stomachs, 78.5 percent consisted of the nymphs of several species of Odonata. *Perithemis seminole, Pachydiplax longipennis* and *Enallagma* sp. were the most common of these odonate species. Other species taken in lesser quantities were *Anomalagrion hastatum, Aphylla williamsoni, Anax junius, Coryphaeschna ingens, Epicordulia regina, Tetragoneuria* sp., and *Cannacria gravida.*

Pearse (1919) observed that Odonata nymphs formed 2.3 percent of the food of 140 black crappie in Lake Wingra, Wisconsin. He states that the dragon-fly, may-fly, and damsel-fly nymphs eaten were those which were found among aquatic plants and my observations tend to support this generalization. Most of the species listed above typically inhabit the vegetated areas of ponds and lakes (Byers, 1930).

Hemiptera such as notonectids and corixids were taken by crappies occasionally but did not appear to be an important part of the diet.

The category "other insects" includes ephemerid nymphs *(Caenis diminuta* and *Callibaetis floridanus),* trichopterans of the family Hydropsychidae, formicinid ants, and Coleoptera *(Hydroporus* sp., *Hydrovatus compressus, Hydrocanthus oblongus,* and forms of the families Lathridiidae and Chrysomelidae). Altogether, their importance was insignificant from the standpoint of quantity and frequency of occurrence.

The relative importance of insects, other than Diptera, to the young and adult crappie in Orange Lake is demonstrated by the differences in the numbers of stomachs in which the insects occurred. Only 8.2 percent of the young crappie had eaten non-dipterous insects, while 23 percent of the adult crappie stomachs contained these food items. It was noted that the period of greatest consumption of Odonata nymphs was February through April, or just prior to the time of emergence of these insects which usually occurs during April, May, and June in Florida.

Crustacea.—Entomostracans are of greater importance to young crappie than to the adults. Of the stomachs of crappie less than 100 millimeters in length, 94 percent contained one or more Entomostraca while only 12 percent of adult crappie took them for food.

Copepoda comprised 84.3 percent of the total number of entomostracans consumed. The forms most frequently taken were *Cyclops* sp. and *Diaptomus* sp. Cladocerans such as *Bosmina* sp., *Daphnia* sp., and *Simocephalus* sp., constituted 14.6 percent of the entomostracan diet of young and adult crappie. Only 1.1 percent of the Entomostraca taken as food were Ostracods.

In a study of the food of 140 adult black crappie in Lake Wingra, Pearse (1919) found that cladocerans constituted 33 percent while copepods and ostracods were insignificant.

From the records of Pearse and others it appears that Entomostraca form a staple though variable item in the diet of crappie. Consumption of entomostracans by crappie appears to be greater in northern waters than in Orange Lake.

The larger Crustacea were eaten throughout the year by 44.4 percent of crappie of all sizes. These Malacostraca form the second most frequently taken food item. Malacostracans occurred in 46.8 percent of the adult stomachs and in 25.8 percent of the young which were examined. They were not observed in crappie less than 61 millimeters, standard length.

An amphipod, *Hyalella azteca,* formed 99 percent of the total numbers of Malacostraca ingested by crappie. *Hyalella* were quite common in the roots of water hyacinths *(Piaropus crassipes)* and were found frequently in the bushy submerged portions of marsh plants.

The fresh-water shrimp *(Palaemonetes paludosa)* comprised only 0.8 percent of the Malacostraca taken by crappie. These crustaceans were common among the roots of floating plants and in such submerged vegetation as *Anacharis* and *Ceratophyllum.* Two stomachs which were examined contained crayfishes.

Occasional food items.—Spiders, represented by two individuals of the families Argiopidae and Erigonidae and one *Ulaborus* sp., were found in the stomach of one adult crappie. Unidentified mites were found in five, and leeches in two crappie stomachs. A few of the fish examined contained traces of eggs of fishes and other undetermined forms.

Bits of *Lemna, Nymphaea,* and some undermined leaves, roots, and stems occurred in a few crappie stomachs. These items are believed to have been taken accidentally.

TABLE 2.—*Frequency of occurrence of six groups of organisms in crappie stomachs during each month—expressed as percentage of total stomachs examined.*

Month	Fish	Diptera Pupae and adults	Diptera larvae	Other insects	Entomostraca	Malacostraca
January	76	14	28	12	15	52
February	61	40	53	29	5	85
March	52	45	34	58	22	67
April	62	30	17	39	4	56
May	90	20	10	40	10	30
June	90	31	31	31	47	44
July	61	29	53	14	35	32
August	71	15	57	12	6	30
September	74	40	40	10	8	36
October	91	29	20	15	4	28
November	97	13	13	6	3	25
December	82	15	20	15	12	40

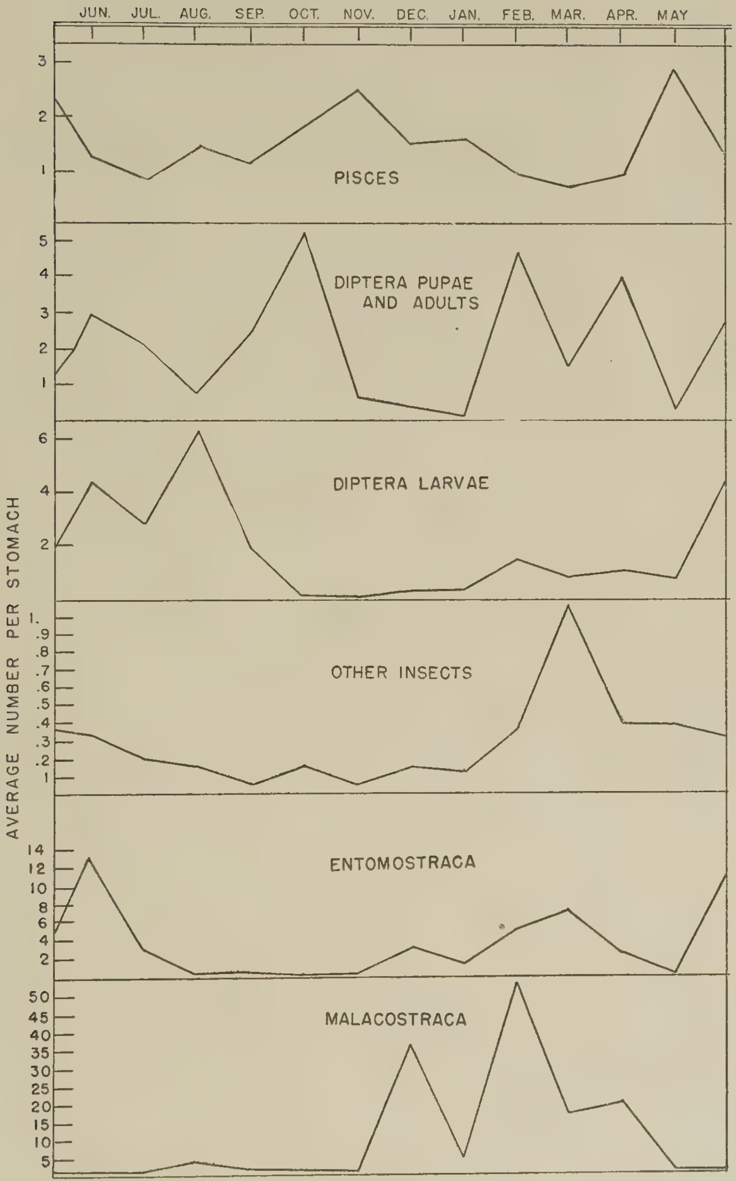

FIGURE 2.—*Average number of organisms of each food group per stomach by months.*

SEASONAL TRENDS IN FOOD CONSUMPTION

Variations in the types and quantities of food organisms consumed by crappie were quite pronounced in some instances as seasons progressed (Table 2, Fig. 2).

An interesting phase of the seasonal trends in feeding activity is the behavior and habits of crappies during the spawning season. Spawning occurred in 1948 during the period from January to April. It was noted that for many days the male crappies were preparing and guarding the nests which were usually situated under the edge of the floating part of the marsh or at the border of the emergent vegetation. Feeding habits of males and females during the breeding season are shown in Table 3.

It appeared that the chief component in the diet of the male crappie during the months shown consisted of vegetation inhabiting forms such as Malacostraca. On an annual basis the food item most frequently taken by both male and female adult crappie was shad. Yet during the breeding season the males ate approximately one-third more malacostracans and one-third less shad than did the female crappie. These differences might be explained on the basis of availability of the forage fishes. Shad were usually found in the open water; hence the male crappie, nesting in the vegetation, fed on Malacostraca. These data tend to confirm Pearse's (1919) conclusion that male crappie do not neglect feeding during the active breeding season.

VOLUME OF VARIOUS FOOD ITEMS USED

The food of the crappie has been interpreted volumetrically to show the relative importance of fish and invertebrate forms. The data shown in Figure 3 were obtained by determining the volume in cubic centimeters of specimens of average-sized *Dorosoma* and *Hyalella* taken by crappie and using these values to translate the numerical data to volumetric units.

TABLE 3.—*Comparison of two food groups taken by male and female crappie during breeding season—January through April.*

Item	January		February		March		April	
	Male	Female	Male	Female	Male	Female	Male	Female
Total stomachs[1]	32	42	31	40	6	38	11	43
Number containing fish	14	42	8	32	4	21	5	29
Percentage containing fish	44	100	26	80	67	55	45	67
Number containing malacostraca	25	12	30	30	5	21	9	22
Percentage containing malacostraca	78	29	97	75	83	55	82	51

[1] Stomachs containing food from fish which could be sexed.

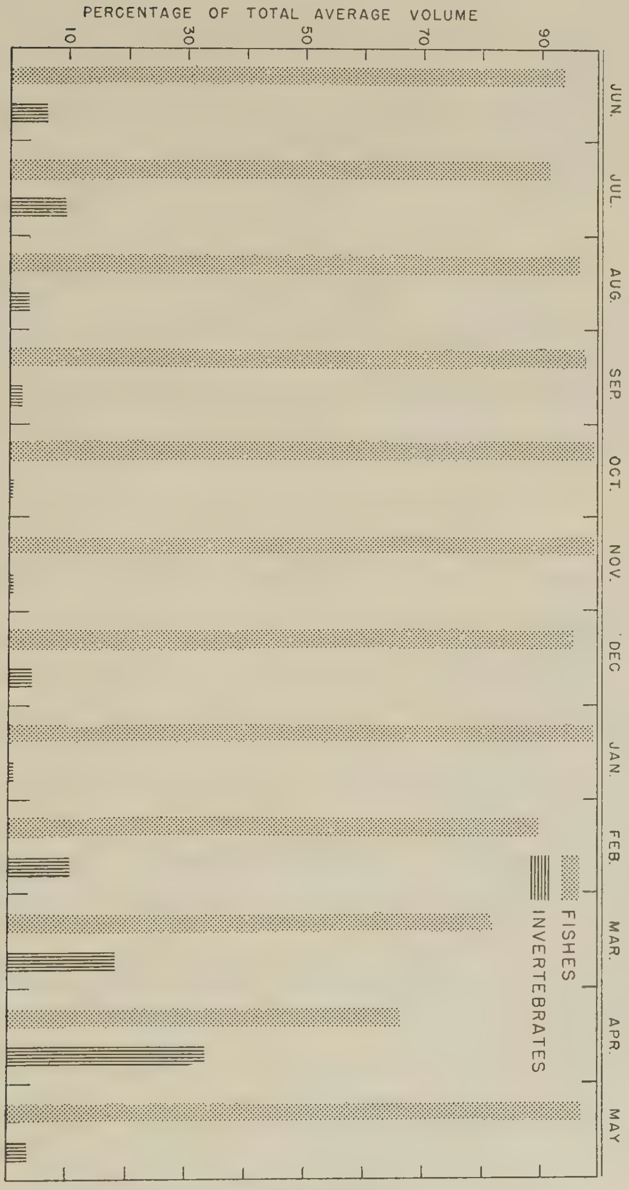

FIGURE 3.—*Average volume per adult crappie stomach of two food groups expressed as percentage for each month.*

From Figure 3 it can be seen that during only 3 months did the average volume of invertebrates amount to over 10 percent of the total average volume of food contained in the stomachs of crappie. The volume of invertebrate food items during February was greatly increased by the large amount of Malacostraca taken. These crustaceans, mostly *Hyalella,* occurred in 85 percent of the adult stomachs, with an average of 53.3 animals per crappie stomach. As shown in Table 2 and Figure 1 these February values represent the greatest frequency of occurrence and the largest average number of organisms per stomach for any one month.

ACKNOWLEGMENTS

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RESULTS OF SOME TAGGING STUDIES OF THE FLORIDA LARGEMOUTH BASS *MICROPTERUS SALMOIDES FLORIDANUS* (LeSueur)

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Abstract

As part of a migration study 1,616 Florida largemouth bass were tagged in six large connected lakes in central Florida. Three-hundred-seventy (22.9 percent) were reported recaptured by hook and line fishing. Some movement occurred between the lakes but no pattern of migration was discernible.

Average interval between release and recapture was 14.7 weeks. More than 84 percent of those recaptured had not moved more than 5 miles from the point of release. Maximum distance traveled was 12.5 miles.

Attempts to obtain growth-rate data on tagged fish failed. Mortality from handling was considered negligible. No significant correlation was found between total length and chances for recapture.

Introduction

Several fish tagging experiments have been underway in Florida since October, 1947. Although other species have been tagged, the present investigation was confined to the Florida largemouth bass in six large lakes of central Florida (Figure 1). The lakes and their approximate areas considered here are: Lake Apopka, 49.2 square miles; Lake Beauclair, 2.2 square miles; Lake Dora, 7.2 square miles; Lake Eustis, 11.3 square miles; Lake Harris, 28.1 square miles; and Lake Griffin, 15.5 square miles, all wholly or partially in Lake County, Florida. These lakes are quite similar in physical characteristics and are for the most part less than 15 feet in depth. Bottoms are composed principally of hard sand with occasional mud coves or other mud bottom areas.

The six lakes are connected by natural streams or canals which are open for navigation and permit free movement of fish. Since Apopka Springs is the source of water for the entire chain of lakes, except Lake Harris and Lake Yale, there is a gradual flow from Apopka through Beauclair, Dora, Eustis, and Griffin to the Oklawaha River which ultimately joins the St. Johns River. Lake Harris flows into Lake Eustis through Dead River, and Lake Yale drains through the Yale Canal into Lake Griffin. These lakes contain most of the important species of fresh-water fish found in Florida (Dequine, 1949). The species sought by the recreational fisherman, in the order of their importance, are the Florida largemouth bass *(Micropterus salmoides floridanus),* the black

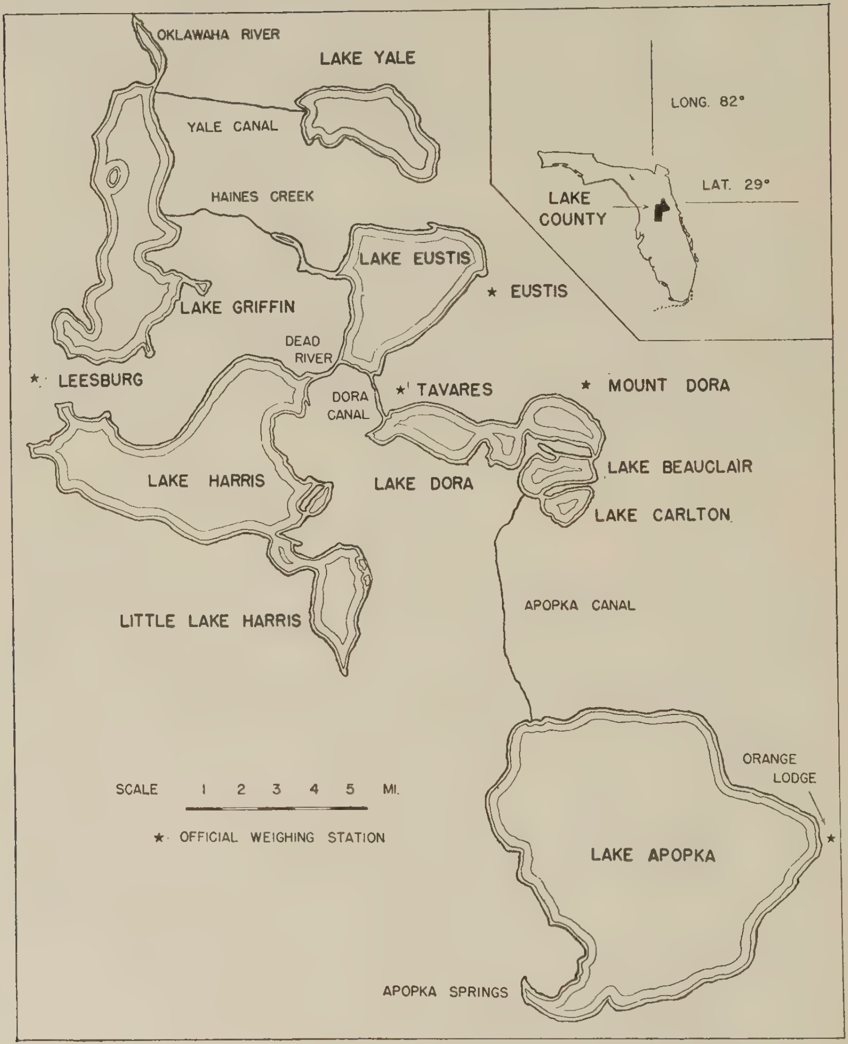
OKLAWAHA RIVER
LAKE YALE
YALE CANAL
HAINES CREEK
LAKE EUSTIS
★ EUSTIS
LAKE GRIFFIN
DEAD RIVER
★ LEESBURG
DORA CANAL
★ TAVARES
★ MOUNT DORA
LAKE BEAUCLAIR
LAKE HARRIS
LAKE DORA
LAKE CARLTON
APOPKA CANAL
LITTLE LAKE HARRIS
SCALE 1 2 3 4 5 MI.
★ OFFICIAL WEIGHING STATION
ORANGE LODGE
★
LAKE APOPKA
APOPKA SPRINGS
LONG. 82°
LAT. 29°
LAKE COUNTY

FIGURE 1.—Map showing relative location, connecting waters, official weighing stations for tagged fish, and other features of six large lakes in Lake County, Florida. Insert (upper right) shows position of Lake County in the State of Florida.

crappie *(Pomoxis nigro-maculatus)*, the bluegill sunfish *(Lepomis macrochirus)*, and the redear or shellcracker *(Lepomis microlophus)*.

The purpose of the tagging studies was threefold: (1) to determine the extent and character of fish migration between the different lakes and within the individual lakes, (2) to determine the extent of utilization of the available bass population by sport fishermen, and (3) to obtain information on age and growth of Florida largemouth bass.

During the early part of the study prizes were offered for all tagged fish caught. In Lake Apopka tagging was done in conjunction with a fish "Rodeo," wherein cash prizes of from 10 to 5,000 dollars were offered for each tag returned. In the other lakes prizes of fishing tackle were given as rewards. Although a number of tagged fish were retaken in the seining operations, only those fish recaptured by hook and line fishing are considered here.

Extensive local publicity was given to the release of the tagged fish through newspapers, posters placed in conspicuous places at all fishing camps and public landings, personal interviews with fishing camp operators, and instruction of local wildlife officers. Chambers of commerce and civic organizations were alerted by personal appearance of the writers. All marked fish recaptured in Lake Apopka were brought in to the official checking station located at the fishing camp of the operator sponsoring the "Rodeo." Fish caught in the other lakes were taken to official weighing stations located in the surrounding towns as shown in Figure 1.

After the prizes were discontinued in the spring of 1949 for all lakes except Apopka where rewards are still given, camp operators mailed in the tags or held them until they were called for. Postage-free envelopes were provided in which to return the tags and information. Agents at these checking stations were instructed in methods of weighing and measuring the fish and provided with facilities for recording data. Periodic visits were made to all checking stations and fishing camps in the area to collect tags and data and to insure maintenance of accurate records.

Methods of Collecting and Marking Fish

With the exception of 51 bass taken in Lake Apopka by hook and line, all of the fish tagged during these studies were taken by haul seines. Upon removal from the pocket of the seine the fish were placed in a live-well boat and held (usually not over 30 to 60 minutes) until the total for the day was collected. Fish having any defects or injuries were discarded and only those appearing to be in good condition were used. All fish were handled by dip net wherever possible except during the actual tagging, weighing, and measuring. During these operations the person handling the fish wore wet cotton gloves. It was found that a three-man team operated most efficiently with one man recording the data while the other two tagged, weighed, measured, and released the fish.

Three sizes of Monel-metal strap tags, serially numbered and suitably identified, were used to mark fish of different sizes. The method of applying the tag is a modification of that used by Eschmeyer (1942) and his associates in Tennessee. The present method differs in that the tags were placed only on the maxillary instead of both the premaxillary and maxillary. Observations on tagged largemouth bass in aquaria showed that the strap tag when placed over both premaxillary and maxillary interfered with the normal opening and closing of the mouth in respiration. It is believed that this constriction of one side of the mouth interferes with the capture of food.

The application of the tag is made by holding the fish by the lower jaw while a slit is made with a pocket knife in the skin between the left maxillary and the premaxillary to receive the tag which is then clinched around the maxillary. Care was taken to make the slit at a point where the tag fitted well over the maxillary in order to prevent excessive movement of the tag. Several fish have been retaken with inflammation at the point of tagging caused by irritation from loose tags. It is almost impossible to remove the tag without removing the maxillary from its base, provided the tag is not as wide as the maxillary and supra-maxillary combined.

Migration of Marked Fish

The locations of tagging operations were described either by latitude and longitude or by well-known land marks. In Lake Apopka a map with a scale of 1 inch to the mile was prepared and marked into grid sections of 1 mile square. Each grid section was numbered and all prominent land marks were shown. Location of capture in Lake Apopka was determined by reference to these grids. On the other lakes location of capture was referred to local land marks and distances traveled were scaled from one-half inch-to-the-mile county maps. All distances were measured in straight lines to the nearest point.

TABLE 1.—*Date of tagging, number tagged, and number and percentage of largemouth bass recaptured by hook and line in six large central Florida lakes.*

Lake	Date of tagging	Number tagged	Number recaptured	Percentage recaptured
Apopka	October 23—Dec. 18, 1947	1046	263	25.1
Apopka	August 10—August 13, 1948	75	4	5.3
Apopka (total)		1121	267	23.8
Beauclair	February 3, 1948	100	13	13.0
Dora	Jan. 27—Feb. 6, 1948	98	29	29.6
Eustis	Jan. 28—Feb. 9, 1948	99	20	20.2
Harris	Jan. 29—Feb. 5, 1948	103	22	21.4
Griffin	Feb. 10—Feb. 13, 1948	95	19	20.0
Total		1616	370	22.9

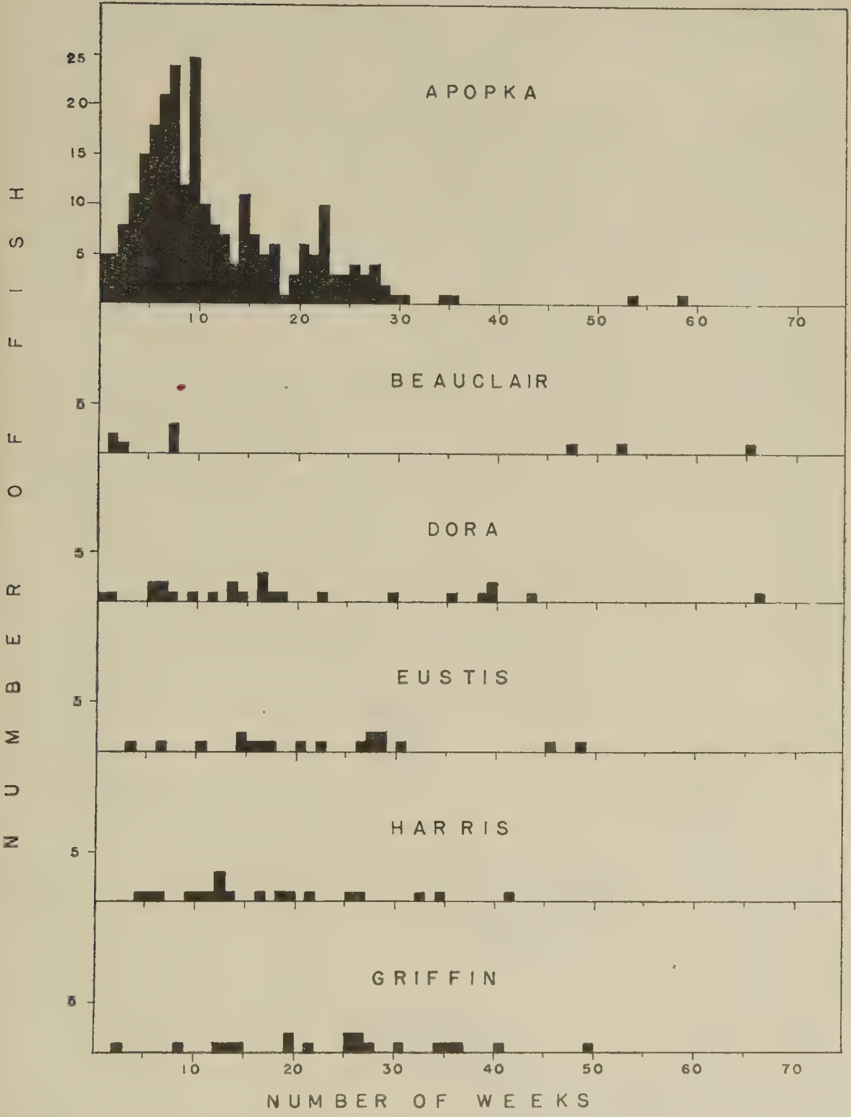

FIGURE 2.—Number of fish reported recaptured by hook and line and number of weeks elapsed between release and recapture of tagged largemouth black bass in six large central Florida lakes.

TABLE 2.—*Percentage of total fish recovered at varying distances from place of marking in six Florida lakes.*

Lake	Number fish recovered with complete data	Miles traveled from point of release												
		0.0-1.0	1.1-2.0	2.1-3.0	3.1-4.0	4.1-5.0	5.1-6.0	6.1-7.0	7.1-8.0	8.1-9.0	9.1-10.0	10.1-11.0	11.1-12.0	12.1-13.0
Apopka	224	46.0	8.9	10.2	10.2	11.2	4.5	3.6	2.7	2.7				
Beauclair	12	16.7	8.3	41.7	25.0				8.3					
Dora	26	19.2	26.9	15.4	11.6	3.8	7.7					7.7		7.7
Eustis	14	28.6	14.3	7.1	21.5					14.3	7.1	7.1		
Harris	18	27.8	16.7		16.7	11.1	5.5	5.5	16.7					
Griffin	14	21.4	21.4	14.2	7.2	14.3	14.3				7.2			

Lake Apopka.—A total of 1,121 tagged largemouth bass were released in Lake Apopka: 1,046 from October to December, 1947 and 75 in August, 1948 (Table 1). Of the total, 267 were recaptured by hook and line fishing, and 224 were accompanied by information considered accurate enough for use in determining extent of migration (Table 2). Fish taken in the same grid in which they were released were considered as having traveled 0.0 to 1.0 miles. Those taken in an adjacent grid were considered to have traveled 1.1 to 2.0 miles, unless a more accurate location of the point of capture was given. All other distances were scaled from the map in a straight line from the centers of the respective grid sections. Data on the distances traveled can be found in Figure 2 and Table 2.

Of the 224 bass tagged in Lake Apopka for which valid data on point of recapture are available 194 (86.6 percent) were recaptured within 5 miles of the location of release. The greatest distance traveled by one fish was 9 miles in 88 days. Sixty-five (29.0 percent) were recaptured in the same grid section in which they were released. No fish tagged in Lake Apopka was known to be recaptured in another lake. A report of the recapture of one of the Apopka fish from Lake Dora could not be confirmed.

Lake Beauclair.—One hundred largemouth bass were captured and tagged in Lake Beauclair. Of the 13 recaptured, 12 were reported with accurate enough information to determine distance traveled. Seven bass were recaptured in Lake Beauclair, two each in Lakes Carlton and Dora, one in Lake Apopka and one in an unknown location. The greatest distance traveled was 7.5 miles in 335 days.

Lake Dora.—Ninety-eight tagged largemouth bass were released in Lake Dora. Of the 29 recaptured, 26 were reported with information considered accurate enough to determine distance traveled. As some difficulty was experienced in obtaining sufficient bass in Lake Dora, 65 were captured in Lake Eustis, towed in the live-well boat through the canal, and released in Lake Dora. Eighteen of the 65 were recaptured; 11 in Lake Eustis, 2 in Lake Harris, 2 in Lake Griffin, and 3 in Lake Dora. Of the 33 originally taken and tagged in Lake Dora, 11 were recaptured; one in Lake Beauclair, one in Lake Apopka, two in Lake Eustis, and seven in Lake Dora. Two bass traveled 12.5 miles in 101 days and 125 days respectively.

Lake Eustis.—Ninety-nine tagged largemouth bass were released in Lake Eustis. Of the 20 recaptured, 14 could be used to determine distance traveled. Of the 51 bass originally taken and tagged in Lake Eustis, 12 were recaptured; eight in Lake Eustis, three in Lake Harris, and one in an unknown location. Of the 48 towed from Lake Harris into Lake Eustis, eight were recaptured; three in Lake Eustis, three in Lake Harris, one in Lake Dora, and one in an unknown location. One bass traveled 11 miles in 197 days.

TABLE 3.—*Numbers and percentages by 1-inch size classes of Florida largemouth bass tagged and recaptured by hook and line in six large central Florida lakes.*

Size class (Total length in inches)	Number of fish														Percentage recaptured
	Lake Apopka		Lake Beauclair		Lake Dora		Lake Eustis		Lake Harris		Lake Griffin		Total tagged	Total recaptured	
	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured	Tagged	Recaptured			
12.0–12.9	74	19	2	0	15	1	11	0	7	1	4	1	113	22	19.5
13.0–13.9	328	78	18	1	29	8	28	2	12	0	28	3	443	92	20.8
14.0–14.9	209	54	18	1	19	7	11	3	16	1	16	1	289	67	23.2
15.0–15.9	150	44	10	3	8	3	9	2	11	3	16	5	204	60	29.4
16.0–16.9	95	30	6	0	5	3	5	2	7	4	13	7	131	46	35.1
17.0–17.9	80	13	4	1	2	0	3	1	4	1	6	1	99	17	17.2
18.0–18.9	73	14	8	2	2	1	4	1	1	0	2	0	90	18	20.0
19.0–19.9	40	4	4	3	2	0	4	3	5	2	3	0	58	12	20.7
20.0–20.9	20	1	10	1	6	2	5	3	3	0	1	0	45	7	15.6
21.0–21.9	17	4	9	0	2	1	5	1	5	1	2	1	40	8	20.0
22.0–22.9	6	0	5	0	6	3	6	2	7	1	2	0	32	6	18.8
23.0–23.9	15	4	1	1	2	0	1	0	3	0	0	0	22	5	22.7
24.0–24.9	12	2	3	0	0	0	5	0	3	1	2	0	25	3	12.0
25.0–25.9	2	0	2	0	0	0	2	0	0	0	0	0	6	0	00.0
Lengths not available[1]	...	...	...	...	....	...	...	...	19	7	...	...	19	7	...
Totals	1,121	267	100	13	98	29	99	20	103	22	95	19	1,616	370	

[1] One field data sheet containing lengths and weights of 19 bass from Lake Harris was blown overboard. Most of the fish recorded thereon were large bass. Seven (36.8 percent) of the 19 bass were recovered. Total lengths reported on capture were 17.5, 20.0, 21.7, 22.0, 22.0, 22.5, and 22.6 inches. Inclusion of these fish in Table 3 would have tended to balance the ratio of the percentage of recapture of larger fish to smaller fish.

Lake Harris.—One-hundred-three largemouth bass were captured, tagged and released in Lake Harris. Of the 22 recaptured, 18 were reported with sufficient information to determine distance traveled. Twenty-one were taken in Lake Harris and the point of capture of one is unknown. One bass traveled 8 miles in 187 days.

Lake Griffin.—Ninety-five largemouth bass were captured and tagged in Lake Griffin. Of the 19 recaptured, 14 were reported with information considered accurate enough to determine distance traveled. All were recaptured in Lake Griffin. One bass traveled 9.5 miles. None of the bass tagged in this or the foregoing experiment has been reported captured from Lake Yale, the Oklawaha River, or the St. Johns River.

Three-hundred-seventy bass (22.9 percent of all bass tagged) were recaptured by hook and line (Table 1). Eschmeyer (1942) recaptured 18.5 percent of 662 largemouth bass tagged in Norris Reservoir, Tennessee, in 1940. He also reported[1] a recovery by hook and line of 20.9 percent of 115 largemouth bass from Norris, and 5.1 percent of 98 largemouth bass in Cherokee Reservoir, Tennessee, in 1947. Ball (1947) reported the recapture by fyke nets and hook and line of 13.5 percent of 52 largemouth bass tagged in 1939-40 in a small Michigan lake. Apparently, Florida fishermen are harvesting as much or more of the available largemouth bass population as are fishermen elsewhere.

TIME BETWEEN RELEASE AND CAPTURE

Figure 2 shows the length of time elapsed between the original tagging and the recapture of the bass by hook and line fishing. The average interval between release and recapture was 14.7 weeks with 315 (92.4 percent) of the fish being taken within 30 weeks of their release. It is believed that the majority of the tagged fish which will be caught by hook and line fishing were recovered within the first 12 months after release as only three returns have been reported subsequently. It is estimated that more than 99 percent of all tagged fish caught in Lake Apopka were reported because the prize value was high and that more than 90 percent of those tagged in other lakes were turned in.

MORTALITY FROM TAGGING

In Lake Apopka 261 (24.4 percent) of the 1,070 bass taken for tagging by seine and 6 (11.8 percent) of the 51 fish taken by hook and line were recaptured. This difference suggests that higher mortality follows release of fish caught on hook and line, or that bass once taken by hook and line are not so readily retaken by the same method. It is believed that the low returns (5.3 percent) of 75 bass tagged in Lake Apopka in August, 1948 can be attributed to excessive mortality caused by tagging in hot weather. However, it is not believed that mortality from handling has caused a loss not calculated in our returns for fish tagged in the cooler months (October-May).

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[1] Letter to senior author, November 1947.

Two experiments were conducted to check this loss. On June 16, 1948, 101 largemouth bass from 8.5 to 16 inches in total length were tagged at the Polk County hatchery near Lakeland, Florida. In order to obtain these fish, the pond in which they had grown from fingerling size was drawn down to an average depth of approximately 4 to 6 inches. The fish were then caught by a small seine and a dip net, tagged, measured, and placed immediately in the kettle of the holding pool. After 101 fish were tagged many showed signs of distress from the high temperature and low water level. The operation was discontinued, and the pond was refilled with fresh water immediately. It was determined by visual estimate that 20 untagged fish remained in the pond. During the course of the tagging, one tagged bass was found dead. The following morning 11 additional bass, 9 with tags and 2 without tags, were found dead. No more dead fish were reported by the hatchery superintendent during the week. As almost identical percentages of tagged (9.9 percent) and untagged (10.0 percent) bass died after these operations, no significant difference in mortality could be attributed to the handling and tagging.

On March 16, 1949, 20 adult largemouth bass varying in total length from 12.5 inches to 25.2 inches were taken by haul seines from Lake Hatchineha in Osceola County and transported with a number of other fish by fish truck to Weekiwachee Springs in Hernando County. These fish all received extremely rough handling at the time of capture and were transported over very rough roads. Upon arrival at the springs, 8 of the bass were tagged and all were placed in a submerged pen built of 1-by-3-inch mesh wire. This pen enclosed a surface area of approximately 1,250 square feet varying from 2 to 10 feet in depth, or approximately 56,000 gallons of continuously flowing spring water with a constant temperature of about 74° F.

As in most of Florida's large limestone springs, the water in Weekiwachee is very clear and visibility is exceptionally good. Consequently all fish in the pen could be seen during daylight hours through an observation tank. On March 22 one large untagged bass was hooked in the lip with an artificial lure and played to exhaustion on a rod and reel for the purpose of taking underwater motion pictures. This bass, readily identified by its size, was found dead the following morning. Three tagged bass were treated similarly on March 23, and all three were found dead the morning of March 24. The other bass lived until March 30 when all fish were released at the conclusion of the experiment. Heavy fungus growths on heads, sides, and tail of most of the bass which appeared on March 17 had almost completely disappeared by March 30. These observations indicate that handling Florida largemouth bass in tagging does not cause a significant loss during the cooler months.

GROWTH OF MARKED FISH

Attempts to interpret the information reported on gain or loss in length and weight between time of release and time of capture have so far been unsuccessful. Of 249 bass reported from Lake Apopka with complete information on weight when checked, 73 (29.3 percent) had gained and 149 (59.8 percent) had lost weight. Twenty-seven (10.8 percent) showed no change. Two explanations may be suggested for this loss in weight following tagging. Either the presence of the tag reduced the feeding efficiency of the largemouth bass, or the habit of the largemouth bass of gorging itself on smaller fish while in the seine causes weights at the time of tagging to be higher than when the fish is taken on a sport fisherman's line.

Of 251 bass reported from Lake Apopka with complete information on length when checked, 67 (26.7 percent) had gained and 165 (65.7 percent) had lost length. Nineteen (7.6 percent) showed no change. The losses in total length can only be explained by inaccuracy of measurement[2], or careless recording. Ball (1947) reports that the growth rate for two tagged largemouth bass and one tagged bluegill sunfish was extremely low as compared with the untagged bass and bluegills in a southern Michigan lake. This information further suggests that the presence of a tag reduced growth rates.

During the early part of the investigation, it appeared that the smaller fish were more readily taken. However, statistical analysis of the data on length of recaptured fish (Table 3) failed to show a significant correlation between total length at tagging and subsequent recapture[3]. Apparently, the size of a Florida largemouth bass has little effect on his chances for capture by hook and line.

SUMMARY

1. A total of 1,616 Florida largemouth bass were tagged and released in Lakes Apopka, Beauclair, Dora, Eustis, Harris, and Griffin.
2. Of the total tagged, 370 (22.9 percent) were recaptured by hook and line fishing.
3. Accurate data are available on point of recapture for 308 of the total recaptured; 122 (39.6 percent) were caught in the 1 square mile area in which they were released; 259 (84.1 percent) were caught within 5 miles of the point of release. Maximum distance traveled was 12.5 miles by two bass.
4. Although there was considerable movement of bass between the more closely connected lakes (Dora, Beauclair, Eustis, Harris) no definite pattern or direction of migration was discernible.

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[2] During the time that length limits were in force on the black bass (prior to October, 1948) the law made the use of fork length habitual. It is believed that many of the lengths reported were fork lengths, rather than total lengths.

[3] The coefficient of correlation (r) between percentage recaptured and total length was —0.42. An r value of nearly ±0.70 would be necessary to be considered significant.

5. Average elapsed time between release after tagging and recapture by hook and line for 341 bass was 14.7 weeks; 166 (48.7 percent) were recaptured within 10 weeks after release; 315 (92.4 percent) were recaptured within 30 weeks after release.

6. Attempts to obtain data on growth rates of Florida largemouth bass were unsuccessful because the tag interfered with feeding or data recorded at the time of capture was inaccurate.

7. Mortality from handling Florida largemouth bass is negligible when tagging is done in the cooler months (October through May).

8. No significant correlation was found between total length at time of tagging and subsequent recapture.

ACKNOWLEDGMENTS

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THE DETERMINATION OF OPTIMUM SIZE OF MESH FOR GILL NETS IN LAKE MANITOBA

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Abstract

A method recently described by W. E. Ricker for determining the size at which fish should be taken to provide maximum sustained yield, is applied to a commercial fresh-water fishery. This method indicates that maximum sustained value to the fishermen would be provided by any gill-net mesh size (stretch measure) between 3 inches and 3¾ inches inclusive. Over this range there is no clear-cut advantage to any particular mesh, although there is probably a slight advantage in one of the smaller meshes.

Introduction

The Central Fisheries Research Station was requested by the Manitoba Government in 1945 to determine the optimum mesh size for use in Lake Manitoba where an extensive gill-net fishery is conducted every winter. Relevant data were collected during the winters of 1945-46 and 1946-47. Although it was not possible to collect sufficient material for a thorough study, enough work was done to justify the making of recommendations for administrative action. In particular, the assumed natural mortality rates used are approximate because a tagging program extensive enough to give accurate values was impractical.

The Lake Manitoba Fishery

Lake Manitoba has a surface area of approximately 1,700 square miles (Fig. 1). Around its perimeter the bottom is composed of rock, clay, or sand and slopes very gradually into deeper water. The middle of each of the three basins which make up the lake have soft mud bottoms. These bottoms are remarkably level and at normal water stages are covered with approximately 18 feet of water in the southern basin and about 15 feet in each of the northern basins. Some idea of the nature of this bottom can be gained from the fact that when gill nets are pulled lengthwise under the ice, they soon wear a groove 2 or more feet deep in the mud. It is probable that originally the lake was considerably deeper, and that the center has filled to form the present basin. It is inferred from verbal information of older fishermen that the lake has filled about 1 foot within the past 50 years.

The major fishery in Lake Manitoba is the winter gill-net fishery. The species sought by the fishermen are pikeperch *(Stizostedion vitreum)*,

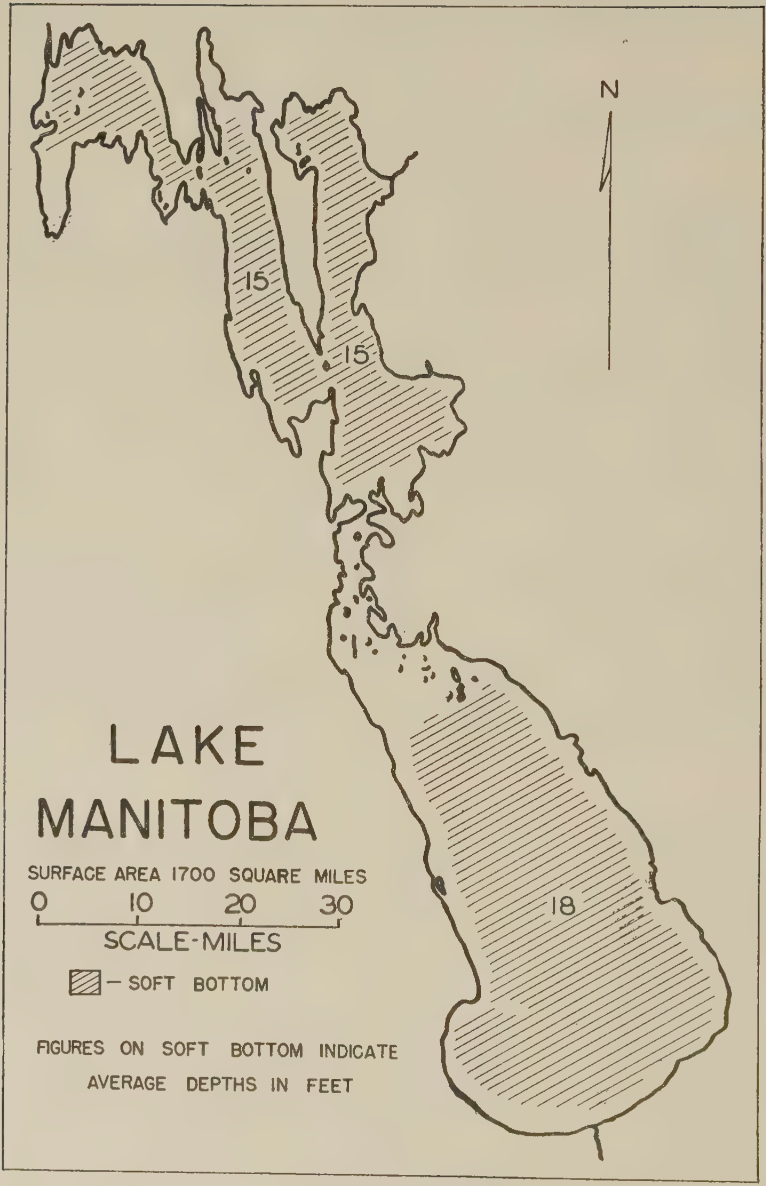
N
15
15
18
LAKE
MANITOBA
SURFACE AREA 1700 SQUARE MILES
0 10 20 30
SCALE-MILES
▨ – SOFT BOTTOM
FIGURES ON SOFT BOTTOM INDICATE
AVERAGE DEPTHS IN FEET

FIGURE 1.—*Lake Manitoba, Canada.*

sauger *(Stizostedion canadense)*, and perch *(Perca flavescens)*. Tullibee *(Leucichthys* sp.*)* are taken in some numbers but at present are of little value. Whitefish *(Coregonus clupeaformis)*, suckers *(Catostomus commersonnii)*, and pike *(Esox lucius)* are of minor importance and several other species including goldeye *(Amphiodon alosoides)* are occasionally caught. Burbot *(Lota lota)* is among the fish taken which have no commercial value.

The fishermen generally work in pairs and use gill nets with mesh sizes ranging from 3¼ to 5½ inches (stretch measure). Initially a line is carried under the ice by a "jigger" to link two holes which are about 90 yards apart. One end of the line is tied to the end of a gill net which is placed on the ice nearby. A man at the other hole hauls in the line while his partner pays out the net. When the whole net is under the ice, marker lines are tied on, and it is allowed to sink to the bottom. Each time the net is to be lifted, a line is first attached to one end so that it will be pulled under the ice, and can be used to re-set the net.

The fish are removed from the nets as soon as they come out of the water and before the fish and nets can freeze. Most of the fish are marketed as fresh fish, and several methods are used to keep them from freezing.

History of the Fishery.—The catch statistics only approximately express the actual catches, especially in the case of the earlier years, but they are useful for comparative purposes. Records of fish production in Lake Manitoba started in 1888. From 1907-1908 until the present, all fishing was done in the winter season only (Fig. 2). Fishing effort was probably low in the early years. Between the winter of 1921-22, when the first records of approximate effort are available, and the winter of of 1925-26 fishing effort increased approximately 400 percent but there has been little increase in effort since then.

With increasing fishing effort there was a rapid increase in recorded production of pikeperch until the winter of 1925-26. Thereafter it fluctuated around a slightly lower level. It seems probable that the increased effort reduced the accumulated stock of older fish, until the fishery was stabilized at a level where fish were taken as they were produced.

In the winter of 1921-22 the legal mesh for gill nets was changed from 4 inches to 3¾ inches (stretch measure). From 1932 to 1940 the use of gill nets with illegal small mesh became more common. This trend probably accounts for the increase during this period in production of perch which until then had been taken in negligible quantities. In the winter of 1940-41 the use of 3¼-inch mesh was legalized and the all-time high production of perch occurred that year. Perch production is now apparently becoming stabilized at a lower level, as did the pikeperch after 1926.

A small production of saugers was first recorded in the winter of 1926-27. Like the perch, the take of saugers increased with increasing

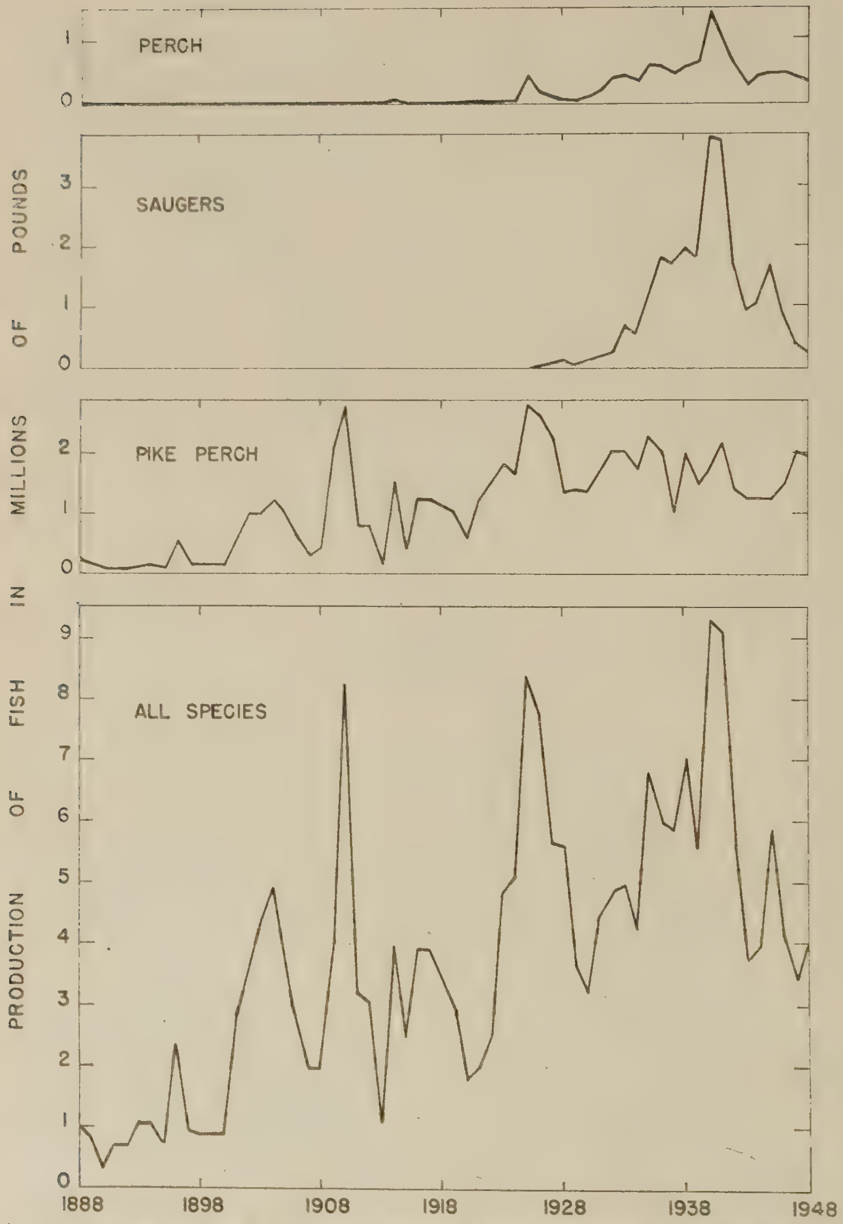

FIGURE 2.—*Production of pikeperch, saugers, perch, and all species combined from Lake Manitoba for the years 1888 to 1948. Legal mesh size was changed from 4 inches to 3¾ inches in 1921-22 and in 1940-41 was further reduced to 3¼ inches. From 1932 to 1940 the use of illegal small mesh gradually increased.*

use of small mesh nets and reached a peak when the 3¼-inch mesh was legalized. Unlike the perch, however, the level of production has apparently not become stabilized. Since the fish are taken at nearly maximum potential size, and since practically every fish caught has been mature for at least one spawning season, it is unlikely that fishing effort has caused the continued decline. This decline may be correlated in some way with the low water levels which existed between 1928 and 1947. With the exception of the years 1935-38, the lake level during this period was consistently 1 to 2 feet below normal. In a lake as shallow as Lake Manitoba this change in level could cause considerable change in the environment. The onset of low water levels corresponded to the first appearance of saugers. Their greatest production coincided with the lowest water level, and the present low production is coincident with a return to above-normal water levels. These facts suggest that a changed environment resulting from changes in water level may have had an important influence on their abundance. Nevertheless, if small mesh nets had never been used, there probably would have been little production even with large numbers of the fish present.

Total production has included several species in addition to those discussed above. Of these other species tullibee has been the most important. Its production, in general, has been governed by demand rather than by supply, and is consequently not a major concern in the management program. The same factor has generally governed the taking of other minor species except whitefish and goldeyes which have never been taken in quantity.

Materials and Methods of Calculation

The approximate size of fish being taken in the commercial nets was determined by measuring and weighing samples from various parts of the lake. In addition, fish were measured and weighed from special small-mesh nets. From the special nets and from the 335 randomly selected commercial nets that were examined, 1,081 pikeperch, 1,041 saugers, 213 perch, 152 tullibees, 14 whitefish, 924 suckers, 76 pike, and 19 burbot were recorded. The gonads of 351 pikeperch, 247 saugers, 570 perch, and 688 tullibee were examined to determine the state of maturity. The length of the fish from the tip of the snout to the fork of the tail and the weight to the nearest ounce were recorded. The size of mesh from which the fish were taken was recorded to the nearest sixteenth of an inch. Scale samples were taken from most of the fish that were measured and weighed. A scale projector was used to determine the ages of 1,050 pikeperch, 975 sauger, and 336 perch from their scales.

Calculation of Optimum Mesh Size for Pikeperch.—Ricker (1945) outlines a method for determining the size at which fish should be caught. The method with minor changes is used in the present calculations to find the most desirable mesh size for Lake Manitoba.

Since gill nets are used in Lake Manitoba, the situation is more complex than that visualized by Ricker. Gill nets take fish over a considerable size range rather than at a particular size. Therefore, the method must be modified slightly by assuming that for each mesh size a given year class is subject to a fishing mortality rate that increases each year until a maximum is reached at the point where the fish reaches a size of maximum vulnerability. The efficiency of the mesh gradually decreases as the fish becomes older, but in the following calculations it is assumed to remain at the maximum value. This assumption has little effect on the conclusions, especially since the natural rate of mortality is assumed to remain constant, whereas it actually increases with age. By calculating the probable effect of using various meshes, the optimum mesh size becomes apparent.

Application of this method requires the following data: (1) the relationship between average weight and age; (2) an estimate of annual natural mortality rate at each age; and (3) an estimate of annual fishing mortality rate at each age. The first information is readily available from age studies. Methods of securing the other data are discussed below.

Calculation of Total Annual Mortality Rate of Pikeperch.—Ricker (1945) recommends that fishing and natural mortality rates be determined by release and recovery of tagged fish. Since such a program would take several years and would be very expensive, a second, less reliable, method has been used.

This method is based on the principle that in a random sample of fish the number in each age class becomes progressively smaller, except for the youngest fish which are not caught in proportion to the numbers present. The ratio between the number of fish of a given age and the number one year younger is presumed to be the fraction which survive from one year to the next. The "average" of these ratios is taken as an approximation of the annual survival rate and the complement of this rate is taken as the approximate annual mortality rate.

In the northern half of Lake Manitoba the average size of the pikeperch caught in any given size of mesh is greater than that of those caught in the southern half. A preliminary examination of the data shows that there is no difference in growth rate and that this difference results from the larger proportion of older fish in catches from the northern half. Since the observed differences could result from unrepresentative sampling, and since a preliminary examination of each half separately suggests the same conclusions for management, all the data are regarded as representative of a homogeneous population.

The samples of fish caught in nets with mesh ranging from 2½ to 5¼ inches show that there is probably some correlation between mesh size and age, but that any mesh takes fish of a wide range in ages (Table 1). The total numbers in each age group are therefore approximately proportional to the total numbers in each age group in the entire

TABLE 1. — *The number of pikeperch of each age group caught by each size of mesh in the samples taken from Lake Manitoba in 1945-46 and 1946-47.*

Mesh[2] size (inches)	Year of Life											
	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
2½	16	8	5	......	......	......	......	......	......	......	......	......
2¾	22	53	4	3	2	1	......	......	......	......	......	......
3	13	39	12	6	1	1	1	......	......	......	......	......
3¼	7	71	106	64	24	3	1	2	1	......	......	......
3½	2	20	35	27	8	1	2	4	1	......	......	......
3¾	......	6	65	67	35	14	4	3	1	......	......	......
4	......	......	3	12	14	12	2	1	1	1	......	......
4¼	......	1	9	51	54	36	18	19	3	2	1	1
4½	......	......	8	6	9	6	5	3	1	......	......	......
4¾	......	......	......	......	......	......	......	......	2	1	......	......
5¼	......	......	......	1	......	......	2	1	2	1	......	......
Totals	60	198	247	237	147	74	35	33	12	5	1	1
Theoretical totals	14	152	291	270	163	74	34	37	8	3	2	2

[2] Each mesh size includes all fish from meshes $\frac{1}{16}$ inch larger or smaller and one half the fish from meshes ⅛ inch larger or smaller.

population except that the nets apparently catch a smaller proportion of the young fish than of older fish.

Since the rate of mortality which characterizes the older age groups does not appear to apply to fish less than 7 years of age (Group VII)[1] it is believed that fish less than this age are incompletely vulnerable to the gear. In view of this assumption only the fish of age VII and older are used in the calculation. The appropriate value for the "average" proportion of fish in each age class which survive from one year to the next is calculated from the totals of Table 1 as follows:

$$\frac{74 + 35 + 33 + 12 + 5 + 1 + 1}{147 + 74 + 35 + 33 + 12 + 5 + 1} = \frac{161}{307} = 0.524$$

It appears, therefore, that under present conditions about 52 percent of the pikeperch in a given age class survive to become one year older, and about 48 percent of them die within the course of a year.

The total numbers in each age group shown in Table 1 are not proportional to the numbers in the commercial catch, since a greater proportion of fish were taken from the more uncommon mesh sizes than from those normally used. The approximate numbers of fish of each age which would have appeared in the sample if a total of 1,050 fish had been taken from commercial nets in proportion to the number of different nets in the lake appear as corrected totals in Table 1. From these totals, annual survival rate was calculated as follows:

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[1] Roman numeral indicates year of life. Since fish were taken in winter, each age group represents completed years.

$$\frac{74 + 34 + 37 + 8 + 3 + 2 + 2}{163 + 74 + 34 + 37 + 8 + 3 + 2} = \frac{160}{321} = 0.498$$

Therefore, about 50 percent survival or essentially the value which was derived from the experimental sample, applies to the sample as corrected for normal commercial gear. Ricker (1948) describes a graphical method of determining annual mortality. This method when applied to the above data indicates an annual mortality rate of 50 percent.

Annual Natural Mortality Rate in Pikeperch.—In order to evaluate the effect of fishing intensity, it is essential to separate the natural mortality rate from the fishing mortality rate. An unsuccessful attempt to estimate the fishing mortality from decline in catch per unit of effort during the fishing season was made early in the study. Such an estimate combined with knowledge of total mortality rate would have permitted evaluation of natural mortality. Since some estimate of natural mortality is essential, the total mortality of 26 percent found in the unfished population of pikeperch in Kakisa Lake, Northwest Territories has been used as natural mortality rate for this study. This lake is similar to Lake Manitoba and has a population of pikeperch which has never been exploited.

THE EFFECT OF THE FISHERY ON PIKEPERCH

Using the method described by Ricker (1945) with certain additional calculations the fate of 100 pounds of age III pikeperch which enter the lake Manitoba fishery was calculated (Table 2). With the assumed natural mortality rate of 26 percent and total mortality rate of 48 percent, instantaneous rates of natural (0.30) and fishing (0.34) mortality were calculated for fishes of age VII and older. Because incomplete vulnerability of younger fish was assumed, additional calculations were necessary for them. Since samples of younger groups indicate a lower mortality than is believed to be normal for fish completely vulnerable to the fishery (approximately 50 percent) instantaneous fishing mortality rates are corrected on the basis of comparison of actual availability (237 in Age VI, Table 1) to probable abundance in population (326 or twice age VII, Table 1). These corrections resulted in instantaneous fishing mortality rates of 0.28, 0.15 and 0.03, for age groups VI, V, and IV respectively.

Examination of the average weight and catch at each succeeding age indicates that any year class entering the fishery attains its greatest weight during fourth year and makes its greatest contribution to the catch at age VI. The calculations of Table 2 represent the status of a single brood year class at succeeding one-year intervals; but since the fishery of Lake Manitoba has been stable for a number of years, it can

TABLE 2.—*The calculated effect of the present fishery in Lake Manitoba on a single year class of pikeperch which enters the catch in its third year (instantaneous natural mortality rate, 0.30).*

Age	Average weight (ounces)	Instantaneous rates			Annual rate of gain	Change in weight	Weight of population	Average weight	Catch
		Growth	Fishing mortality	Gain in weight					
III	9.8	.38	.00	0.08	0.08	8	100	104	0
IV	14.0	.30	.03	−0.03	−0.03	−3	108	106	3
V	20.7	.24	.15	−0.21	−0.19	−20	105	95	14
VI	25.1	.20	.28	−0.38	−0.32	−27	85	72	20
VII	30.7	.18	.34	−0.46	−0.37	−21	58	48	16
VIII	34.4	.16	.34	−0.48	−0.38	−14	37	30	10
IX	47.4	.14	.34	−0.50	−0.39	−9	23	18	6
X	52.6	.12	.34	−0.52	−0.41	−6	14	11	4
XI	57.5	.10	.34	−0.54	−0.42	−3	8	6	2
XII	65.0	.10	.34	−0.54	−0.42	−2	5	4	1
XIII	68.5	.10	.34	−0.54	−0.42	−1	3	2	1
							2		
Total catch from 100 pounds of age III fish entering the fishery									77

be considered to represent the status of all age groups in the population. It is therefore evident that from every 100 pounds of age III fish entering the fishery 77 pounds will be harvested by the fishermen.

Since the present fishery uses many mesh sizes, it is necessary to determine the probable effect of exclusive use of specific sizes if total fishing effort and present mortality rates remain essentially unchanged. The necessary calculations are like those used in Table 2 except that differential selectivity of the various meshes affects the value of instantaneous fishing mortality in the younger age group. For example, the 3¼-inch mesh is assumed to be fully efficient in catching age V fish but not in catching age IV. Only 71 age IV fish are recorded as taken by 3¼-inch mesh (Table 1) while twice 106 (the number of age V) or 212, are expected so that the instantaneous rate of fishing mortality for age IV is actually about $\frac{71}{212} \times 0.34 = 0.12$.

Calculations on this basis were made for 3-inch, 3¼-inch, 3¾-inch, and 4¼-inch mesh gill nets when each was used exclusively. By considering the calculated weight of fish in each age group and the relationship between age and weight, the approximate weight of fish in each size range was calculated. For example, at the observed rate of growth, 73 percent of age IV pikeperch weighed between 0.5 pound and 1 pound. Referring to Table 2, the calculated catch of age IV fish would be 3 pounds per annum per unit entering the fishery, of which, 73 percent or 2.2 pounds would be composed of fish weighing between 0.5 pound and 1 pound. By similar calculations 1.5 pounds of age V fish, and 0.1 pounds of age VI fish would be within the same size range. No other age classes make significant contributions to the weight range so the fishery visualized by Table 2 should produce 3.8 pounds per annum per unit entering the fishery, or 4 pounds in round numbers. Values for different weight ranges and mesh sizes together with total calculated catch from each mesh size are shown in Table 3.

These values indicate that exclusive use of 3-inch mesh would produce the greatest sustained annual yield of fish (92 pounds). However, the important factor in a commercial fishery is total value rather than total volume. Inquiries among fish dealers and others indicate that on the average pikeperch which weigh between 1 pound and 1.5 pounds are 25 percent less valuable than those which weigh more, while those under 1 pound in weight have half the value of large fish. Under these conditions the value of fish from fisheries with 3-inch, 3¼-inch, 3¾-inch, and 4¼-inch mesh gill nets, respectively, would be in the ratio 70:73:72:64. It therefore appears that from the standpoint of value it makes little difference what mesh size is used in the pikeperch fishery over the range of 3 inches to 3¾ inches.

These calculations assume that the exclusive use of the various meshes would not change the growth rate. This assumption probably is not strictly correct. Miller (1947) has shown that a greater fishing intensity can lead to faster growth. It is also evident that a change in mesh size would certainly lead to a change in fishing intensity for the younger fish. Kennedy (1948) has presented evidence that an increase in growth rate of saugers and to a lesser extent of pikeperch in Lake Manitoba followed the reduction in mesh size during the winter of 1940-41. It is probable that the exclusive use of 3¾-inch mesh would not change the present rate of growth since the smaller fish would be taken at about the same rate as in the present fishery (Table 1). Presumably a mesh smaller than 3¾ inches would cause an increase in growth rate, while a larger mesh would cause a decrease. Therefore, average sizes of the fish taken by 3-inch and 3¼-inch mesh would be slightly higher than those indicated in Table 3, and the total catch would be slightly greater.

Table 3.—*The calculated effect of exclusive use of various mesh sizes on sustained yield of pikeperch in Lake Manitoba in terms of catch in pounds out of every hundred pounds of fish which survive until the winter of their third year.*

Mesh size (inches)	Fish size (pounds)							Total catch in pounds
	Less than ½	½–1	1–1½	1½–2	2–3	3–4	Over 4	
Present mixture	0	4	20	27	16	7	3	77
3	1	29	30	18	9	3	2	92
3–¼	0	13	31	25	11	5	2	87
3–¾	0	3	22	28	16	6	3	78
4–¼	0	0	5	22	22	10	6	65

Effect of Mesh Size on Spawning of Pikeperch

The gonads of 351 pikeperch taken at random from the Lake Manitoba catch were examined and the state of maturity was recorded. All of the age III fish were immature, but 7 percent of the age IV, 49 percent of the age V, 67 percent of the age VI, 75 percent of the age VII, and 90 percent of the age VIII, and all of age IX and older fish were mature. With these values, and the calculated catches from each age class (Table 2) it was possible to estimate the approximate number of mature fish of each age group which would survive the fishing season, if a particular mesh size was used exclusively. According to these estimates, from every 100 fish present in the lake at age II, a 3-inch mesh would permit 27, a 3¼-inch 37, a 3¾-inch mesh 51, and a 4¼-inch mesh 77 fish spawnings. Each time that a mature fish survived a fishing season (practically equivalent to survival until the spawning season) would count as a "fish-spawning."

Kennedy (1947) outlines a situation where a much smaller population of mature pikeperch than that which would result from fishing

3-inch mesh net exclusively has provided an abundance of young that probably was all the lake in question could support. It is therefore concluded that the use of 3-inch or larger mesh gill nets in Lake Manitoba would not in any way interfere with adequate spawning.

SAUGERS

By calculations similar to those used above for pikeperch, the annual mortality rate for saugers was determined to be 70 percent. By using this value and assuming the same natural mortality rate as for pikeperch, the calculated weight of fish expected by exclusive use of 3-inch, 3¼-inch, 3¾-inch, and 4¼-inch gill nets, respectively, would be in the ratio 130:134:99:77. It is therefore apparent that 3-inch or 3¼-inch mesh would be preferable for the taking of saugers.

A closer examination of the data indicates that since the beginning of the 1942-43 season the annual mortality rate has been about 76 percent, while prior to the end of the 1941-42 season it was about 42 percent. Since maximum fishing effort for saugers probably was reached in the winter of 1940-41, it seems unlikely that this sudden increase represented an appreciable increase in fishing mortality. It is much more likely that it represents an increase in natural mortality, probably resulting from the changes in water level mentioned above. Recent natural mortality probably has been considerably higher than that assumed in the calculations. Obviously a greater natural mortality would result in a greater relative advantage from the use of a smaller mesh.

Prior to 1942 the total mortality rate was approximately the same as that of the pikeperch or slightly less. If a natural mortality similar to that of the pikeperch is assumed, the considerably slower growth of the sauger would result in a greater advantage from using 3-inch or 3¼-inch mesh than that calculated above for pikeperch.

At the present time the production of saugers is almost negligible. If the lake level again drops, or perhaps when the lake fills further, it is presumable that saugers will again become abundant. Should this happen, the 3-inch or 3¼-inch mesh would be the most advantageous gill-net size for optimum sauger production. The exact magnitude of the advantage cannot be estimated because "normal" values for mortality rates cannot be determined from the rapidly declining population now present.

As in the case of pikeperch, the probable effect of mesh size on growth rate has been neglected in the above calculations. If it is taken into account, the advantage of 3-inch or 3¼-inch mesh size is further emphasized. Since 98 percent of the saugers taken by 3-inch mesh gill nets are mature, there is no danger that the exclusive use of any of the meshes considered would interfere with adequate spawning.

PERCH

It is apparent from inspection that the most advantageous gill-net mesh for taking perch would be 3 inches or even smaller. The average weights of perch of ages III, IV, V, VI, VII, and VIII are 1.0, 2.9, 5.2, 6.9, 8.7, and 11.0 ounces respectively. No perch older than age VIII appeared in the sample. The annual mortality is about 60 percent. Three and three-quarter-inch mesh takes few perch, 3¼-inch takes mostly age VII and VIII fish with a few age VI, while 3-inch mesh catches ages V, VI, VII, and VIII. Almost all of age IV and older fish are mature.

OPTIMUM MESH SIZE FOR ALL SPECIES

At the present time pikeperch are so much more important than the other two species that the latter can be almost disregarded. Under these conditions all mesh sizes between 3 inches and 3¾ inches are almost equally advantageous. There is probably a slight advantage in the use of 3-inch or 3¼-inch mesh because they would improve production of perch and saugers. If the numbers of either or both perch or saugers were to increase appreciably, or if the relative value of small pikeperch were to increase, then there would be a distinct advantage in the use of 3-inch or 3¼-inch mesh. On the other hand, if the relative value of small pikeperch were to decrease appreciably with no increase in numbers of perch or saugers, the 3¾-inch mesh would become the most advantageous. Whichever mesh is selected for the exploitation of the three important species would be suitable enough for taking the other species considering their relatively unimportant roles in the fishery.

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OBSERVATIONS ON MORTALITY RATES IN FISHED AND UNFISHED CISCO POPULATIONS

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Abstract

Square Lake, Alberta, has an area of 2.5 square miles and possesses a dense cisco population which has not been fished. Baptiste Lake, area 8 square miles, has a cisco population which has been fished, and Lesser Slave Lake, area 462 square miles, possesses a cisco population which has been at first lightly, then heavily fished. Catch curves from these lakes are compared and mortality rates calculated. It is shown that the mortality rate in an unfished lake may exceed the total mortality rate in a lightly fished lake. The suggestion is made that natural mortality rate is influenced by fishing mortality rate. It is further argued that predictions of the course of a fishery based on catch curves must be made with great caution due to large unpredictable changes in rate of recruitment which follow changes in fishing intensity.

Introduction

The value of assessment of mortality rates in fishery management is now well established, but the use of this information is limited by the difficulty of separating the component parts of total mortality. From a catch curve the rate of total mortality can be calculated but it gives no clue to the proportions caused by natural and fishing mortalities. Therefore, as Ricker (1948) has pointed out, catch curves from unfished waters are of particular interest since the mortalities which may be calculated from them are unaffected by fishing. The purpose of the present discussion is to compare the catch curve of the cisco *(Leucichthys artedi tullibee)* from an unfished lake with those from two exploited lakes.

Unfished Lakes

Square Lake, Alberta, has an area of 2.5 square miles and a maximum depth slightly more than 100 feet. It has been cut off from its drainage system by low water for about 12 years preceding the spring of 1947. During this period there has been no opportunity for emigration or immigration of ciscoes and no fishing has been permitted. From November, 1946 to May, 1949, a total of 1,187 ciscoes was taken in gill nets of 2¾-inch mesh, stretch measure.

The age distribution of these fish (Table 1) has been expressed as a catch curve by plotting the logarithms of the frequencies of each age group against age (Figure 1). A full discussion of such curves has been given by Ricker (1948, 1949).

TABLE 1.—*Age frequency distribution of ciscoes (Leucichthys artedi tullibee) in samples from Square, Baptiste, and Lesser Slave lakes.*

Age Group	Lake								
	Square	Baptiste	Lesser Slave						
	1946-1949	1945	1941	1942	1943	1944	1945	1947	1948
1	6	5	0	0	0	12	0	19	4
2	2	241	0	0	0	32	18	313	374
3	259	87	3	4	6	24	7	60	116
4	533	250	7	1	9	48	12	4	6
5	267	163	15	14	27	95	16	3	0
6	95	79	50	56	38	146	17	1	0
7	21	12	31	10	17	150	24	0	0
8	3	0	12	0	2	35	5	0	0
9	1	0	0	0	0	2	1	0	0

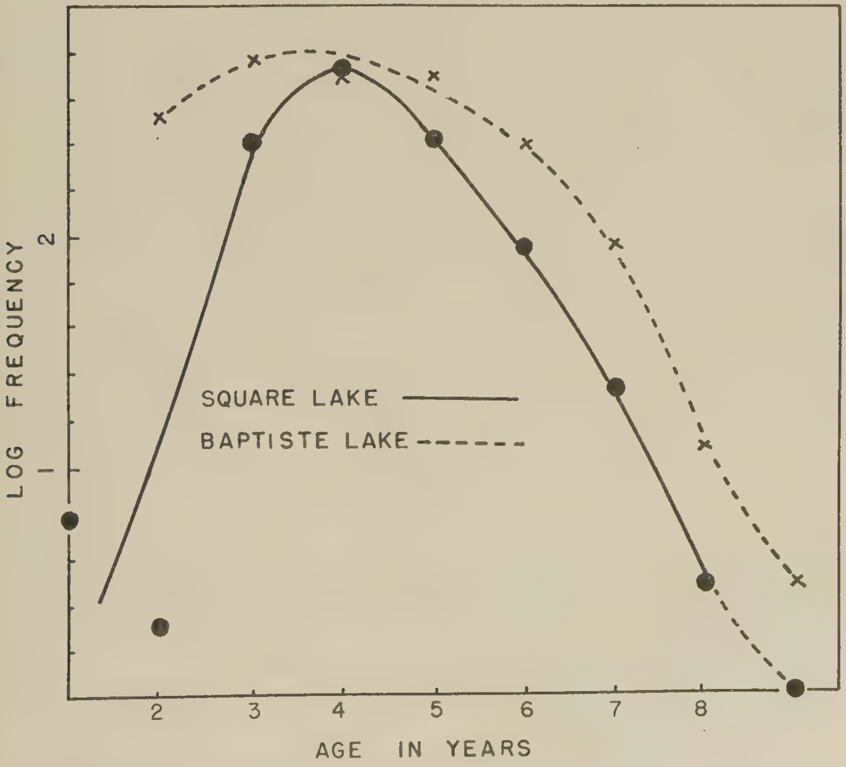

FIGURE 1.—Catch curve for 1,187 ciscoes from Square Lake, 1946-1949 (solid line), and 837 ciscoes from Baptiste Lake, 1945 (broken line).

In Figure 1 the ascending left limb of the curve represents young fish which were too small to be completely vulnerable to the fishing gear. Consequently, this portion of the curve is of little significance. Fish of age group IV are almost completely vulnerable and age group V may be assumed to be entirely vulnerable. If each age group was equally abundant when it entered the fishery, then the slope of the descending right limb of the curve represents the survival from one year class to the next. The fact that data obtained over a three-year period have been combined to plot the curve helps to smooth it and minimizes variations due to uneven recruitment. That recruitment must have been fairly uniform is shown by the smoothness of the curve. By taking tangents on this right limb of the curve, survival rates and mortality rates have been calculated for age groups V, VI, and VII, as follows:

Age	*Survival rate*	*Mortality rate*
V	41.3 percent	58.7 percent
VI	29.5 percent	70.5 percent
VII	20.0 percent	80.0 percent

A survival rate for age group VIII is not calculated because the slope of the curve is influenced by age group IX, represented in the collection by only one fish. Since it is unlikely that the survival rate would increase from the eighth to the ninth year, it is advisable to ignore the last concave portion of the curve.

The question of which of these three survival rates most nearly describes the actual survival rate in the population as a whole now arises. The first rate, 41.3 percent for age group V, is probably too high, since age group IV is not completely vulnerable to the gear used and so tends to reduce the slope at age group V. The third value, 20 percent at age group VII, is probably too low, because the small mesh nets may allow a disproportionate number of 7-year and older fish to escape. This possibility makes the curve too steep and the calculated survival rate too low. By elimination, then, the best value of survival would seem to be 29.5 percent at age VI. This value results in the astonishingly high natural mortality rate of 70.5 percent.

FISHED LAKES

Having examined mortality rates in an unfished lake, it is now of interest to study catch curves of the same species of fish from lakes which have supported a commercial fishery. Baptiste Lake is comparable in size to Square Lake with an area of 8 square miles and a maximum depth of 90 feet. It has supported an irregular cisco fishery for some years (Table 2). The commercial gear employed was the same as that used to sample Square Lake.

During the period of March to October, 1945, a total of 837 ciscoes was taken and analysed for age composition (Table 1). A catch curve plotted from these data would not be highly reliable for survival rate

TABLE 2.—*The annual production of ciscoes in Baptiste Lake, 1942-1946, and in Lesser Slave Lake, 1940-1948—expressed in pounds.*

Year	Baptiste Lake	Lesser Slave Lake
1940–41	....	1,504,900
1941–42	....	1,993,900
1942–43	27,936	1,770,600
1943–44	188,306	1,475,900
1944–45	149,950	1,349,020
1945–46	37,750	1,491,980
1946–47	......	3,556,590
1947–48	....	4,502,570

calculations because the sample was taken in one season only. Ricker (1949) smoothed his curves, derived from somewhat similar data, by taking a running average of three. This method has been used for these data and a reasonably smooth curve (the broken line in Figure 1) obtained. In this way error caused by fluctuation in recruitment is minimized. The slope of the right limb of this curve has been used to calculate survival rates at ages VI and VII of 55 and 22.9 percent, respectively. When these figures are compared with those for Square Lake it is evident that total mortality is not very different in the two lakes despite the fact that in Baptiste Lake they represent natural plus fishing mortality, while in Square Lake they show natural mortality only.

Square and Baptiste Lakes are small and perhaps, present atypical mortality conditions. Considerable data are available from Lesser Slave Lake, a much larger lake (462 square miles), which has been subjected to extremely heavy fishing since 1940 (Table 2). Before the 1940-41 season the catches were light with an annual average of only 63,000 pounds for the 5-year period ending in 1939.

The age composition of 1,848 fish caught in 2¾-inch commercial gill nets and made up of separate samples taken each year from 1941 to 1948, except 1946, was determined (Table 1). The samples in four of these years were rather small and their reliability must be established. In Table 3 are shown the separate catches from different parts of the lake which were used to make up the samples of 1947 and 1948. It is clear from these data that any single sample of 100 fish gives a reliable

TABLE 3.—*The age composition of small samples of ciscoes taken in Lesser Slave Lake in 1947 and 1948, expressed as percentage of total sample.*

Date	Size of Sample	Age group					
		1	2	3	4	5	6
Aug. 9, 1947	100	11	80	6	3	0	0
Oct. 3, 1947	100	4	83	10	0	2	1
Nov. 4, 1947	200	2	75	22	0.5	0.5	0
Aug. 24, 1948	100	0	77	23	0	0	0
Sept. 21, 1948	100	0	68	29	3	0	0
Sept. 21, 1948	100	0	74	25	1	0	0
Sept. 22, 1948	100	1	79	19	1	0	0
Sept. 22, 1948	100	3	76	20	1	0	0

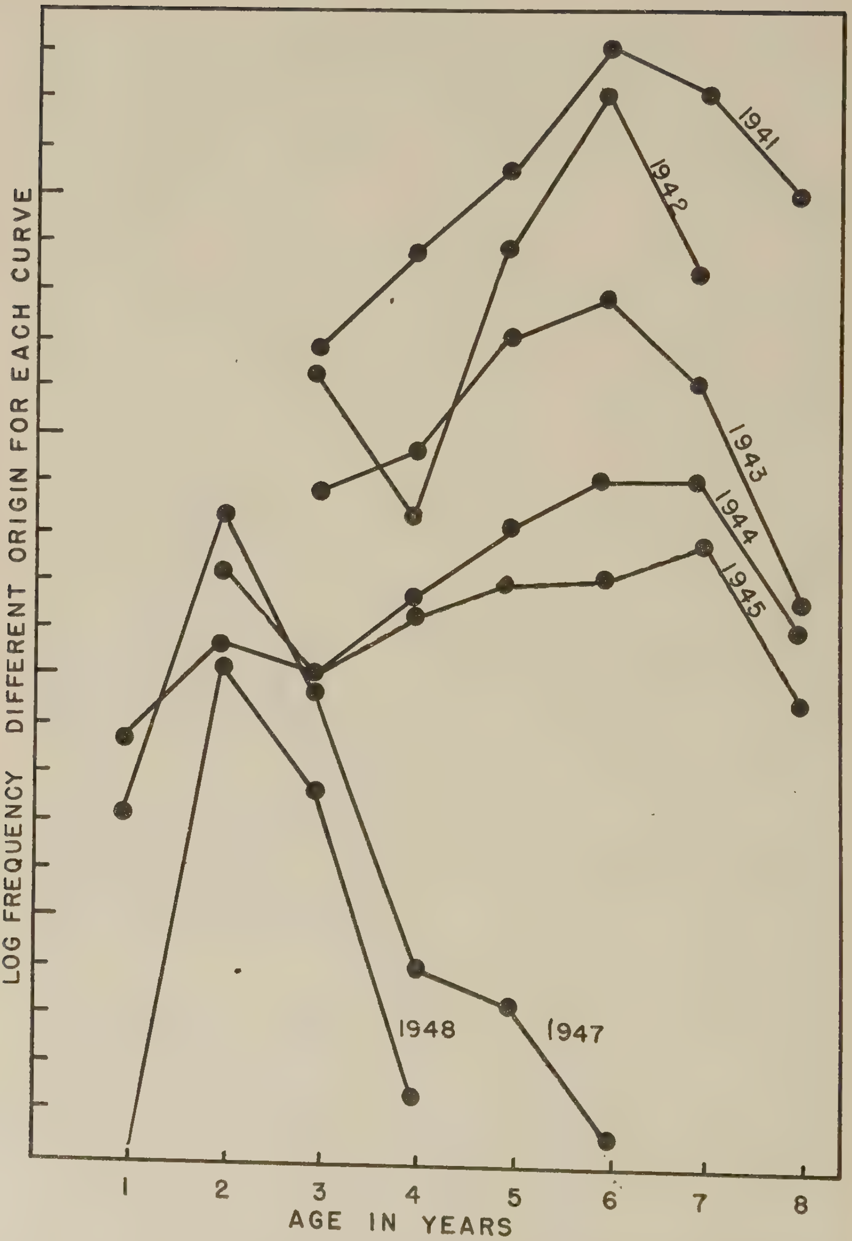

FIGURE 2.—Annual catch curves for 1,848 ciscoes from Lesser Slave Lake taken in the years 1941-1948 inclusive, except 1946.

picture of the age composition of the portion of the population taken by the nets. It appears safe, therefore, to use the data provided by the small samples for the years from 1941 through 1945.

Catch curves have been plotted for each year for which data are available. An analysis of these curves in chronological sequence reflects the history of the fishery. The curve for 1941 shows the situation at the end of a period of mild exploitation. There is a long period of recruitment shown by the long left limb of the curve, and the survival rate of the fully vulnerable portion of the population is 39.8 percent. Evidently the rate of natural mortality in this larger lake is much less than in Square Lake or Baptiste Lake.

The curves of 1942-1945 indicate the effect of the increased rate of exploitation. First, an increasing number of the younger, less vulnerable fish are caught (shown in the extended left limbs of the curves) and second, the survival rate of the fully vulnerable age groups has decreased to approximately 20 percent.

During the fishing season 1946-47 the catch was more than doubled. The 1947 catch curve shows that age groups IV to VI have the survival rate (about 20 percent) which was in effect up to 1945, but that the new survival rate of only 6.91 percent is apparent in the young age groups. These young groups, which were formerly only lightly exploited, under increased fishing form the bulk of the fishery. The fishing pressure increased still more in the 1947-48 season with the result that the older age groups have disappeared and all of the population 2 years of age and older is subjected to the terrific mortality of 93-95 percent. The curves in Figure 2 illustrate what is probably a clear case of overfishing. At present rates of fishing, a collapse of the fishery appears to be imminent.

DISCUSSION

The data presented above indicate that the greatest caution must be exercised in the interpretation of catch curves. Two points in particular should be emphasized.

First, a catch curve from an unexploited population in all probability will give a distorted picture of the magnitude of natural mortality when it is applied to a fished population. Thus in Square Lake the total mortality (all from natural causes) is as great as the total mortality in Baptiste Lake, where there is both natural and fishing mortality. In both these small lakes the mortality is greater than in Lesser Slave during a period of mild exploitation. From 1941 to 1945 the total mortality in Lesser Slave Lake, which was subjected to heavy fishing, is only slightly greater than in Square Lake, where there is no fishing. The comparison of the mortalities in these three lakes, then, suggests that fishing mortality decreases natural mortality.

Second, the rate of recruitment responds in an unpredictable way to heavy fishing. This fact makes the interpretation of catch curves difficult. For example, the curve for Lesser Slave Lake in 1943 shows that recruitment is not complete before age VII and that no fish survive beyond age VIII. Total mortality is 88.5 percent of the first fully vulnerable age group and 100 percent of the next group. Such a curve suggests that exploitation of the fishery was dangerously excessive. Actually, however, the fishery went on to yield two and a half times as great a weight of fish. This production was accomplished by increased recruitment which made the 2-year fish appear to be almost completely vulnerable. Increased vulnerability can be accounted for partly by increased growth rate (approximately 8 percent from 1941 to 1947) and partly by what must be an increased production of young. The foregoing considerations must be taken to mean that catch curves can be used only with considerable reservation as bases for accurate forecasts of the course of a fishery when the fishing pressure is variable.

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SOME CONSIDERATIONS IN THE USE OF FISH GROWTH DATA BASED UPON SCALE STUDIES[1]

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ABSTRACT

In comparing growth data it is frequently necessary to convert standard lengths to fork or total lengths. The deviations of calculated from observed lengths in three series of data indicated that with samples of 15 or more fish the errors of conversion were small when the conversion factors are based upon the same fish or fish from the same area measured by the same biologist. Mean lengths based on 15 or more fish would have a deviation of less than 1 percent under such conditions. When conversion factors based upon fish from other areas measured by other biologists were used the error was as much as 4 to 5 percent. The differences in body-scale relationships between fish of the same species from different collections make further study necessary. A standard deviation of about 3.5 percent was noted in calculated growths from paired scales in several series of fishes. Comparison of lengths at capture avoids errors due to body-scale relationship but introduces difficulties due to differences in time of capture. It is suggested that lengths at time of last annulus might be more valid for comparative purposes. The coefficients of variation from three growth studies were from 4 to 11 percent. Variations among calculated growth rates of fish from these populations were such that samples of about 240 would be needed to bring the sample mean within 1 percent of the true mean with 95 percent confidence.

INTRODUCTION

Age and growth studies based on the scale technique have become firmly established as important parts of most fishery biology and management research investigations. It seems desirable at this time to analyze critically the use of these data and to arrive at some estimate of the degree of accuracy which can be attached to such data. This paper does not deal with the validity of the annulus nor with inaccuracies which may arise from accessory annuli or from misinterpretations of scale markings, but with some of the variations in measurements and in sampling.

CONVERSION OF LENGTH MEASUREMENTS

Standard, fork, and total lengths have been used at various times and by various investigators. (For discussion see: Royce, 1942; Carlander and Smith, 1945; Ricker and Merriman, 1945; Hile, 1948). It is therefore necessary to measure all fish by all three methods or to use conversion factors if comparisons are to be made with other published data. The conversion factors are usually calculated by dividing the average total length (or fork length) by the average standard length of a group of fish. Usually the fish are grouped into length classes to determine whether the conversion factor changes with the size of the fish, but in other cases there is no indication that this procedure has been followed.

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[1] From the Iowa Cooperative Fisheries Research Unit, sponsored by the Iowa State Conservation Commission and the Industrial Science Research Institute of Iowa State College, with the cooperation of the Fish and Wildlife Service, U. S. Department of the Interior.

Estimates of errors arising from the use of conversion factors were obtained with three series of data: 509 saugers, *Stizostedion c. canadense,* and 344 yellow perch, *Perca flavescens,* from Lake of the Woods and measured by L. E. Hiner and the author, and 101 yellow perch from East Lake, Iowa, measured by W. M. Lewis and T. English. Standard, fork, and total lengths of each fish were recorded, and then fork and total lengths were computed for each fish using various conversion factors. The deviations of the computed lengths from the measured lengths were tabulated to indicate the frequency of deviation of a certain magnitude. Even when conversion factors based upon the same series of data were used, deviations of up to 7 percent of the length were observed, but over 50 percent of the computed lengths deviated less than 1 percent from the measured lengths. When conversion factors based upon measurements on the same species of fish in another population and measured by other biologists were used, average deviations or biases of up to 4 percent were quite frequent. Comparisons of the deviations under various conditions were made by determining the size of sample needed to bring the mean converted length within a designated percentage of the mean measured length, with 95 percent confidence (Table 1).

TABLE 1.—*Sizes of sample*[1] *needed to bring the mean converted lengths within a designated percentage of the mean observed lengths, with 95 percent confidence, when various conversion factors are used.*

Conversion factor	Number of combinations tested	Deviation Percentage less than				
		5	4	3	2	1
Computed from same sample as the data....	6	1	1	1–3	3–6	7–12
Computed from another sample from the same lake........................	4	1	1	1–4	4–6	13–145
Computed from sample from another population measured by same biologists.......	4	1	1	1–4	4–8	9–34
Reported by other biologists..............	21	1–30	1-∞	1-∞	3-∞	12 ∞

[1] Sample size determined according to binomial theorem using the frequencies of the deviations of the computed from the measured lengths as probabilities.

These data indicate that errors caused by the use of conversion factors derived from the same fish or even by the same biologist using fish from another population may be fairly small and the average deviations may be less than 1 percent with samples of moderate size. When it is necessary to use conversion factors derived for the same species by other biologists, the probable deviation may well be as much as 4 percent and perhaps in other studies might be even higher.

Part of these errors of conversion may be the result of not using the best methods of deriving the conversions since the use of a single conversion factor implies that the relationship between the two lengths is rectilinear and passes through the zero point of the abcissa and ordinate. It would appear, however, that the major source of variation and error is not in the method of calculating the conversion factors since the deviations are moderately low when using data from the same lake and the same biologists. The variations between measurements from different areas and different biologists appear to be much more significant.

BODY-SCALE RELATIONSHIP

In most growth studies where the growth has been calculated from the scale measurements, it has been assumed that the ratio of scale length to body length is constant although many studies have indicated that direct-proportion calculations are not valid and that the body-scale relationship is not even rectilinear (for recent summaries of this problem see Schuck, 1949 and Lagler, 1949). This relationship differs between species and apparently even between different populations of the same species.

TABLE 2.—*Body-scale relationship for several populations of yellow pikeperch.*

Body of Water	Number of specimens	Standard length millimeters	Relationship between standard length (L) and anterior scale radius (R)
Wisconsin Lakes[1]			$\frac{L}{Lc} = \frac{R}{Rc}$
Clear Lake[2]	215	100–400	$L = 36 \text{ mm.} + 2.35\, R$
Lake of the Woods[3]	4,455	50–660	$L = 20 \text{ mm.} + 5.887R - 0.0538R^2 + 0.000349R^3$
Lake Vermilion[4]			$L = 24 \text{ mm.} + 2.31R - 0.0107R^2 + 0.00003R^3$
Leech Lake[4]	144	59–557	$L = 38 \text{ mm.} + 1.634R - 0.00325R^2 + 0.00000966R^3$
Cass Lake[4],[5]	102	191–465	$L = 15 \text{ mm.} + 1.86R - 0.003512R^2 + 0.00000864R^3$
Boulder Lake[4]	17	145–375	$L = 15 \text{ mm.} + 2.377R - 0.01011R^2 + 0.0000243R^3$
Lake Mille Lacs[4],[5]			
1941	248	160–511	$L = 15 \text{ mm.} + 2.511R - 0.0095R^2 + 0.0000487R^3$
1942	140	148–426	$L = 15 \text{ mm.} + 3.198R - 0.014454R^2 + 0.00003627R^3$
1943	92	144–457	$L = 15 \text{ mm.} + 2.674R - 0.01215R^2 + 0.0000322R^3$
Portage Lake[4]	23	150–340	$\text{Log } L = 0.8283 + 0.7147 \text{ Log } R$

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[1] Schloemer and Lorch (1942) state: "All calculations were made with the assumption that the growth of the scale along its anterior radius and the growth of the body in length are in direct proportion. This assumption has been proven valid by the work of Deason, still unpublished." Dr. Ralph Hile states in personal correspondence that Deason's "best fit" was a line with an intercept of 50 millimeters standard length. Several others have calculated the growth rate of yellow pikeperch using the direct proportion formula.

[2] Cleary, 1949.

[3] Carlander, 1945.

[4] Carlander, Kenneth D. A typewritten report to the Bureau of Fisheries Research of the Minnesota Department of Conservation. "Relationship between scale radius and body length of walleye pike, *Stizostedion vitreum vitreum* (Mitchill)." Invest. Rept. No. 15, 26 pp. 1944.

[5] In these lakes, the starting point of the curve was arbitrarily set at 15 millimeters because there were insufficient numbers of small fish to determine this point.

TABLE 3.—*Growth calculations on a hypothetical yellow pikeperch, using the various body-scale relationships.*

Relationship used[1]	Calculated length in millimeters at each annulus				
	1	2	3	4	5
Direct Proportion	100	200	250	300	325
Clear Lake	126	215	260	305	327
Lake of the Woods	137	220	258	301	324
Lake Vermilion	139	210	247	292	318
Leech Lake	127	211	253	299	324
Cass Lake	121	212	256	302	326
Boulder Lake	140	217	253	295	319
Lake MilleLacs					
1941	111	194	241	290	320
1942	151	238	273	309	328
1943	141	220	257	298	322
Portage Lake	143	235	276	314	332

[1] See Table 2.

The body-scale relationship has been determined for a number of populations of yellow pikeperch, *Stizostedion vitreum vitreum* (Mitchill) (Table 2). The numbers of specimens are admittedly too small to permit accurate determination of body-scale relationship in some of these lakes but the data give some indication of the variations which may be expected between different populations. These differences are more evident when the growth rate is calculated for one fish using each of these relationships (Table 3). The growth rates were calculated from the corrected body-scale relationship in the manner described by Hile (1941).

Part of the variation here demonstrated may be caused by collection of scales from different parts of the body. Most of the scales from Lake of the Woods, Lake Vermilion, Leech Lake, Cass Lake, Boulder Lake, Portage Lake, and Lake Mille Lacs in 1943 were collected by the author. Key scales were not selected but the scales were all collected from an area just below the lateral line and even with the spinous dorsal fin. The collections for the 3 years on Lake Mille Lacs were each made by different lake survey crews and variations in method of scale collection may account for the differences in body-scale relationship. The differences were so great that the collections could not be combined in a study of body-scale relationship.

Differences in the body-scale relationship of scales taken from different parts of the body and suggestions that errors may result in growth calculations when the scales are not taken from limited areas have been reported by Esdaile (1912), Parrott (1933), Dannevig and Høst (1931), Robertson (1936), Kaganovskaya (1937), Jensen (1938), Ottestad (1938), and Phillips (1948) but more study on this problem is needed, particularly in species other than trout.

In studies of fish growth at the University of Minnesota (Eddy and Carlander, 1942), two scales from each fish were measured and the growth rate calculated from each on a direct proportion basis with no corrections for body-scale relationships. Treloar (1936, p. 139) pointed

TABLE 4.—*Standard deviations of paired calculations of lengths at each annulus, from two scales from each fish.*

Species and locality	Number of pairs	Estimated standard deviation of supply	
		Millimeters	Percentage of calculated lengths
Tullibee, *Leucichthys artedi tullibee*, Gull Lake	3,312	6.1	3.8
White sucker, *Catostomus commersonii*, Cass Lake	1,690	5.7	2.5
Pike, *Esox lucius*, Birch Lake	1,810	9.4	2.9
Rabideau Lake	1,355	11.9	3.5
Yellow pikeperch, *Stizostedion vitreum*, Birch Lake	3,815	8.1	3.3
Largemouth black bass, *Micropterus salmoides*, Long Lake	925	7.5	4.2
Black crappie, *Pomoxis nigro-maculatus*			
Bush Lake	715	4.9	3.7
Big Lake	500	5.2	4.2
Vadnais Lake	930	4.1	3.3

out that in such a case an estimate of accuracy of measurement may be computed. Half of the difference between the two measurements is equal to the standard deviation, and the mean standard deviation multiplied by the factor 1.7725 will yield a satisfactory estimate of the standard deviation of the supply when the series is large. A standard deviation of about 3.5 percent occurred as a result of differences in the calculated lengths based on two scales from the same fish (Table 4). Presumably the scales came from approximately the same part of the body in each case although the need for particular care in selecting scales was not recognized at the time these specimens were collected. From the formula described by Harris, Horvitz, and Mood (1948), it was calculated that the variation caused by these differences in body-scale relationship would be reduced (with 95 percent confidence) to less than 1 percent of the mean with a sample of 63 fish, or to less than 2 percent with 21 fish, or 3 percent with 11 fish.

Because errors arise from differences in body-scale relationships, some biologists prefer to dispense with calculated lengths and make comparisons only on the basis of lengths at capture of fish in different age classes. One of the major difficulties is that fish from the same age

TABLE 5.—*Number of specimens needed so that the sample mean will be within a specified percentage of the true mean, with 95 percent confidence, in 19 out of 20 cases.*[1]

Allowable deviation in percent	Yellow pikeperch	Yellow bass	White bass
1	196	230	247
2	57	70	67
3	29	35	35
4	19	21	21
5	14	15	15

[1] See text for discussion.

class must often be compared even though some of the fish were caught early in the growing season and others several months later. It is suggested that the length at the time the last annulus was formed be determined on a direct proportion basis and thereby disregard the growth during the current season. Errors due to differences in body-scale relationship are minimized by calculating lengths at a recently formed annulus.

In detailed studies on the growth rates of fish in one population, where the body-scale relationship can be determined for that particular population, calculated lengths should not be discarded, since much information might then be lost: *e.g.,* growth during various calendar years.

SIZE OF SAMPLE

Harris, Horvitz, and Mood (1948) describe a method of computing the size of sample needed to bring the mean of the sample within given limits of the population mean. Growth data on 2,898 yellow pikeperch from Lake of the Woods indicate that the coefficients of variation for the calculated lengths at the end of the first 7 years of life varied from 4.5 to 8.4 percent. Data on 290 yellow bass, *Morone interrupta,* from Clear Lake, Iowa (Lewis and Carlander, 1948) indicate coefficients of variation from 4.1 to 10.2 percent. Data on 118 white bass, *Lepibema chrysops,* from Clear Lake, Iowa (Lewis, 1949) indicate coefficients of variation from 2.8 to 11.0 percent. The central value of the range in each case was used in the estimation of sample size (Table 5). It would appear that samples of about 240 fish are needed to insure that the sample mean will be within 1 percent of the population mean and that with samples of 70 fish the mean will be within 2 percent. These calculations, of course, assume that the samples are representative of the population. Any selectivity of sampling will effect the results even if the sample size is increased.

CONCLUSION

Although these examples give some estimates of the magnitude of the errors which may be expected from various sources, the errors may be very different under other conditions. Tests similar to these should be applied at every opportunity to determine the magnitude of the errors in the study being carried on at that time.

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GILL NETS FOR SAMPLING FISH POPULATIONS IN MINNESOTA WATERS

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Abstract

Reliability of standard experimental gill nets for estimating comparative size of perch, pikeperch, and pike populations is considered in the light of 31 series of gill-net catches from Minnesota lakes. Factors influencing the catch of gill nets are discussed. Because of the wide range of errors associated with means of series of gill-net catches, comparison of catch means at a probability level greater than 80 percent appears to be not practically feasible. A table showing error of means of series of net catches at this probability level is included.

Introduction

In northern waters gill nets have long been used to sample fish populations. The use of such passive fishing gear is largely a matter of practical necessity. More direct methods for estimating the size and composition of fish populations, such as seining, poisoning, and marking and recovery techniques, frequently are not applicable to large natural lakes.

Gill nets have been used to obtain fish for many types of fishery studies, but in addition it has often been assumed that the catch of identical gear under similar conditions is somewhat proportionate to the size of the fish population. This assumption has led to expressing net catches in terms of the unit of effort, such as catch per standard gang of gill nets per day (Rawson, 1947) and gill-net indexes (Moyle, Kuehn and Burrows, 1950). Such catch units have been used to estimate, in general terms, the comparative size of the fish population sampled. In Minnesota the mean catch per standard set has been compared with a state-wide average catch for the same species. The method and validity of comparing catches, either with state-wide averages or with mean catches from other lakes or the same lake at other times, are dependent upon an understanding of catch variability and reliability of averages of combinations of sets. It is with this aspect of the interpretation of net catches that the present paper is concerned.

Two other aspects of the problem of interpreting gill-net catches are selectivity of gear and seasonal variation in catch. These are not considered here, but it might be pointed out that an understanding of them depends upon a better understanding of the reliability of netting as a sampling method.

Comments on the reliability of gill nets as a sampling gear have been made by several fishery workers. Rawson (1947) who fished Lake Athabaska with "standard gangs of gill nets, each 300 yards in length —set for 24 hours in 36 localities" interpreted these catches as "some indication of the density of the fish population." Carlander,[1] after several years of intensive gill-net fishing in Lake of the Woods, concluded that:

> Although it is realized that measures of abundance based on gill-net catches may often lead to errors, it is believed that valuable information may be secured if enough samples are taken and if it is realized that the data so secured are not measures but estimates of abundance.

Description of Gear and Sampling Methods

Gill nets fished as part of Minnesota lake surveys are of the "experimental" type widely used by fishery workers in the Lake States. They are 250 feet long, 6 feet deep, and contain five 50-foot sections of webbing, the meshes of which are 1.5-, 2-, 2.5-, 3-, and 4-inch stretch measure. During a lake survey the nets are so placed that all habitats and, presumably, the entire fish population are sampled. In general, the sets are of two types: those above the thermocline for warm-water fishes and those below the thermocline for trout, tullibee, and other cold-water species. Nets are usually raised in the morning after they have fished about 24 hours. They are moved to a new location before being reset.

In the past the catch of each species of fish has been recorded as catch per 100 feet of net in 24 hours (the gill-net index). It now appears that from the statistical viewpoint, catch data are more useable if recorded as catch per 250-foot set per day. The 37 series of gill-net catches in Table 1 are so expressed. To eliminate as many variables as possible all gill-net sets listed in Table 1 have the following characteristics: (1) all sets are of standard 250-foot experimental net; (2) all sets were fished for 1 day and each series of catches was made in a single lake within a few days; (3) all sets were made during the summer months, mostly July and August; (4) all sets, as far as can be determined from the field data, are from above the thermocline and in the main body of the lake considered; and (5) each series represents scattered sets made expressly for sampling the fish population of the lake.

The catches in Table 1 are from 14 lakes, all of which are larger than 500 acres. They are, for the most part, fairly typical pikeperch waters and for this reason the catches considered are of yellow pikeperch *(Stizostedion v. vitreum)*, yellow perch *(Perca flavescens)*, and pike *(Esox lucius)*. Other species were taken but were not common in many of the catches. It will be noted from Table 1, that usually the series of pike catches tend to have the smallest means; yellow perch

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[1] Carlander, Kenneth D. (1942). *In* An investigation of Lake of the Woods, Minnesota, with particular reference to the commercial fisheries. Ms. Minn. Dept. Cons. Fish. Res. Inv. Rep. No. 42, Vol. 1, p. 155.

TABLE 1.—*Distribution of 37 series of gill-net catches from Minnesota lakes. Series ranked in order of size of mean catch.*

Lake[1]	Species[2]	Number of sets	Number of sets with O fish	Catch range numbers of fish	Mean $\bar{x}$	Percentage of sets below mean	Standard deviation s	Percentage of sets within range	
								$\bar{x}+s$	$\bar{x}\pm 1.2\bar{x}$
Mw	E	30	12	0–4	0.9	40.0	1.1	93.3	93.3
K	E	18	10	0–4	0.9	55.5	1.0	83.3	83.3
F	E	15	5	0–5	1.3	66.6	1.5	86.7	86.7
St	S	19	9	0–6	1.3	73.7	1.9	84.2	84.2
B	E	15	4	0–3	1.4	73.3	1.6	93.3	100.0
St	E	19	8	0–6	1.4	57.8	1.7	84.2	84.2
N	E	13	5	0–6	1.6	61.5	2.1	84.6	92.3
F:	S	15	3	0–6	1.8	66.6	1.9	86.7	86.7
St	P	19	10	0–16	2.1	73.7	3.9	89.5	94.7
C	E	31	6	0–10	2.7	61.3	2.8	83.9	90.3
I	E	15	2	0–6	2.8	53.3	3.4	100.0	100.0
Mw	S	30	4	0–8	3.4	53.3	2.4	73.3	96.0
P	S	16	3	0–9	3.6	56.3	3.2	81.3	87.5
Mt	S	22	7	0–10	3.7	59.1	3.6	73.3	81.8
N	P	13	2	0–16	3.8	69.2	4.7	84.6	84.6
Bp	E	15	1	0–17	4.3	73.3	4.5	86.6	93.3
Me	E	12	2	0–11	4.3	58.3	4.1	83.3	83.3
P	E	16	1	0–13	5.5	62.5	3.7	62.5	93.8
C	S	31	2	0–46	8.0	67.7	9.2	90.3	93.5
Mi	S	11	1	0–21	8.1	54.7	6.2	72.7	90.9
I	S	15	0	1–18	9.1	53.3	6.0	53.3	100.0
K	P	18	0	2–26	10.2	66.6	7.2	72.2	88.8
Mt	E	22	1	0–39	10.7	63.6	8.4	81.8	95.5
K	S	18	0	2–59	11.2	83.3	12.9	94.5	94.5
Me	S	12	0	3–25	11.2	50.0	6.8	75.0	100.0
Bp	S	15	0	2–27	13.7	60.0	10.4	60.0	86.7
Mw	P	30	0	1–75	15.6	70.0	15.9	90.0	90.0
Me	P	12	1	0–93	18.7	75.0	26.9	83.3	91.6
Bp	P	15	0	2–44	22.7	53.3	13.8	80.0	100.0
B	S	15	0	5–52	23.8	46.6	14.7	66.6	100.0
F	P	15	0	1–94	26.9	73.3	26.8	80.0	86.7
I	P	15	0	6–64	31.1	53.3	15.6	73.3	100.0
Mi	P	11	0	9–57	36.4	54.5	15.9	63.6	100.0
P	P	16	0	14–143	44.7	62.5	32.1	87.5	93.8
B	P	15	0	1–116	47.6	60.0	30.5	80.0	93.3
C	P	31	1	0–165	53.6	51.6	39.6	77.7	96.8
S	P	14	0	48–187	96.9	57.1	43.0	35.7	100.0
All sets	....	664	....	....	....	61.2	....	81.5	92.0

[1] B—Blackduck; Bp—Big Pelican; C—Cass; F—Forest; I—Island; K—Kabetogama; Me—Melissa; Mi—Mille Lacs; Mt—Minnetonka; Mw—Minnewaska; N—North Star; P—Pokegama; S—Spider; St—Sturgeon.

[2] E—*Esox lucius;* P—*Perca flavescens;* S—*Stizostedion v. vitreum.*

tend to have the largest means and the means of pikeperch series tend to be of intermediate rank. However, there is considerable overlap and it appears that the catch distribution pattern of all three species is similar. They are therefore considered together.

The number of gill-net sets in the 37 series of Table 1 ranges from 11 to 31. Mean catches of the series range from 0.9 to 96.6 fish. It will be noted that the catch of any series extends over a considerable range and that in each series the portion of the range above the mean is greater than that below it. Usually, the majority of the catches took fewer fish than the mean catch. Specifically, in 35 of the 37 series more than half the catches are smaller than their respective means, and if all catches of all series are considered, 61.8 percent of the catches are smaller than their respective means. This may be contrasted to the 50-50 ratio expected in normally distributed populations.

Effect of asymmetry of the distribution of the catches is also evident when standard deviation is calculated for each of the series. In all but five of the 37 series the mean plus or minus the standard deviation includes more than the expected 68 percent of the sets and if all sets of all series are considered this range includes 81.5 percent of the sets. In the series with small means the standard deviation approximates the mean in size, but the ratio of standard deviation to the mean tends to increase as the size of the mean increases.

Factors Influencing the Catch of Gill Nets

The problem of estimating comparative sizes of fish populations from gill-net catches is generally similar to that presented in "quantitative" sampling of plankton, bottom fauna, and bacterial populations of waters. All such sampling assumes that it is possible to obtain truly representative and measured portions of the population sampled. Theoretically such samples should be taken at random from a uniformly and randomly distributed population. It is obvious to any field biologist that even the most carefully considered sampling of plant and animal populations in their natural habitats can only approximately meet theoretical qualifications for true random sampling. As was noted by Ricker (1937) sampling methods and statistical approaches that are valid for some species of organisms in a mixed population may not be valid for others in the same population.

Interpretation of gill-net catches is further complicated because gill nets are passive fishing gear in which the fish must catch themselves. This fact makes the catch dependent upon factors other than the randomness of the sampling and the size of the population sampled. The principal additional factors are: (1) movement of the fish; (2) shapes and structure of the fish; and (3) the associative pattern or grouping of the individuals of any species or assemblage of species of fish. It appears that movement and shape of the fish of any species influences the size of the mean catch. The associative pattern is more apt to be shown in the distribution pattern of the catches. Irregular grouping of fishes tends to be reflected in catches of irregular size and such irregularity of catch is apt to be more evident when mean catches are small. In large populations the catch of any one net is more apt to be influenced by several groups of fish than in a small population and a better sampling of the entire associative pattern of the population can be obtained. The series of catches in Table 1 show that as the size of the mean catch increases, the dispersion of the catches, expressed as ratio of mean to standard deviation, tends to decrease.

When net catches are evaluated on a comparative basis, shape and structural peculiarities of fish, which cause nets to be selective for certain species, can be disregarded. Such selectivity of gear is constant for any species of fish in all waters. It must be assumed that movement and associative patterns for any species of fish will be similar under similar conditions if any consideration is to be given gill-net catches as a quantitative method.

It should be emphasized that sampling of fish populations with gill nets is quite different from sampling a randomly distributed population of static and non-associated entities—such as beans in a bag. The size of a gill-net catch is a product of the size of the population sampled and the movement of the fishes making up the population. Also, calculated catch "error" of a series of gill-net catches reflects not only vagaries of sampling but is also influenced by the associative pattern of the fishes.

How representative are gill-net catches of a fish population and its movement and associative patterns? To this question there is at present no certain answer. Since the aquatic habitat in any lake is far from uniform, the best that can be hoped for is a representative catch obtained by setting nets in and through all of the habitats present. At present it appears that net catches made above and below the thermocline should be considered separately. Perhaps in large lakes catches should be considered by localities as was done by Miller and Kennedy (1948) in Great Bear Lake.

Interpretation of Gill-Net Catches

Gill-net catches from Minnesota lake surveys have been interpreted in two ways. (1) The mean catch of any species of fish taken in a series of standard sets has been compared with the state-wide mean catch per standard set for the same species. (2) The mean catch of any species taken in a series of sets has been compared with the mean catch of the same species taken from the same lake under similiar conditions but in a different year.

Both of these problems of comparison of catches can be approached through standard statistical procedures if it is assumed (1) that the sampling is random (actually the sampling is more "representative" than "random") and (2) that fish association and movement is similar under similar conditions. It should be noted that most Minnesota netting is done during July and August and the state-wide gill-net indexes, for the most part, represent catches made during these months. As has been pointed out the distribution of the catches in Table 1 is skewed but this seems not to present a serious objection to the use of methods applicable to normally distributed populations. Standard errors drawn from a skewed population will tend to be distributed normally.

If the sampling is considered to be valid, then the reliability of the mean of series of catches can be estimated from procedure yielding t values and probabilities estimated from a table of t. This method is best illustrated by problems.

Problem 1.—What are the odds that an average catch of 4.2 pikeperch in 11 standard gill-net sets represents a pikeperch population larger than that which might be represented by a state-wide average catch of 2.0 pikeperch per set? *Possible solution.* Calculate standard error for the series of pikeperch catches. Considering the state-wide average catch as a "true mean," find the value of t by the usual method (see Snedecor 1940, p. 56). In this case t is found to have a value of 2, which when looked up in a table of t under 10 degrees of freedom, is found to be associated with a probability of about 0.1. It appears that the odds are about 9 to 1 that an average catch of 4.2 pikeperch in 11 sets represents a population larger than that which might be represented by the state-wide average catch of 2.0 pikeperch per set.

Problem 2.—What are the odds that a mean catch of 15 perch in 9 gill-net sets made in July, 1948, represents a population larger than that which might be represented by a mean catch of 10 perch in 8 sets made in the same lake in July, 1949? *Possible solution.* Calculate standard error for both series of perch catches and use a method for determining standard error of the difference between means. Simpson and Roe (1939) give such a formula for small samples. With such an approach it appears that the odds are about 3 out of 4 that a mean catch of 15 perch in 9 sets represents a population larger than a mean catch of 10 perch in 8 sets.

The objection may be raised that too many assumptions are made in the foregoing calculations to allow safe estimation of the reliability of catch means in this manner. Because this difficulty exists and because it is of considerable practical value to have a more rapid proximate method, the problem was approached empirically from the catch data in Table 1.

Where frequent comparison of catch means is to be made it is desirable first, that the reliability of means be compared at the same probability level and second, that the standard error be expressed in terms of the mean itself. In an attempt to meet these two conditions Table 2 has been prepared from the catch data in Table 1. Table 2 expresses ranges of reliability (or error) associated with "true" catch means of

TABLE 2.—*Approximate confidence limits at the 80+ percent probability level associated with "true" means of series of gill-net catches that are distributed similarly to those in Table 1.*

Number of sets	Mean catch of series of gill-net sets—number of fish							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
2	.03–.97	.1–1.9	.1–2.9	.1–3.9	.4–4.6	.4–5.6	.5–6.5	.6–7.4
3	.12–.88	.2–1.8	.4–2.6	.5–3.5	.8–4.2	.9–5.1	1.1–5.9	1.2–6.8
4	.17–.83	.3–1.7	.5–2.5	.7–3.3	.8–4.2	1.2–4.8	1.4–5.6	1.7–6.3
5	.20–.80	.4–1.6	.7–2.3	.8–3.2	1.1–3.9	1.4–4.6	1.6–5.4	1.9–6.1
6	.23–.77	.5–1.5	.7–2.3	.9–3.1	1.2–3.8	1.5–4.5	1.8–5.2	2.1–5.9
7	.25–.75	.5–1.5	.8–2.2	1.0–3.0	1.4–3.6	1.6–4.4	1.9–5.1	2.3–5.7
8	.27–.73	.5–1.5	.8–2.2	1.1–2.9	1.4–3.6	1.7–4.3	2.0–5.0	2.4–5.6
9	.28–.72	.6–1.4	.8–2.2	1.1–2.9	1.4–3.6	1.8–4.2	2.1–4.9	2.4–5.6
10	.29–.71	.6–1.4	.9–2.1	1.2–2.8	1.5–3.5	1.9–4.1	2.2–4.8	2.5–5.5
12	.36–.69	.6–1.4	.9–2.1	1.2–2.8	1.6–3.4	1.9–4.1	2.2–4.8	2.6–5.4
15	.33–.67	.7–1.3	1.0–2.0	1.3–2.7	1.7–3.3	2.1–3.9	2.4–4.6	2.8–5.2
20	.35–.65	.7–1.3	1.1–1.9	1.4–2.6	1.8–3.2	2.2–3.8	2.6–4.4	3.0–5.0
30	.39–.61	.8–1.2	1.1–1.9	1.5–2.5	1.9–3.1	2.3–3.7	2.7–4.3	3.1–4.9
40	.40–.60	.8–1.2	1.2–1.8	1.6–2.4	2.0–3.0	2.4–3.6	2.8–4.2	3.3–4.7
50	.41–.59	.8–1.2	1.2–1.8	1.6–2.4	2.1–2.9	2.5–3.5	2.9–4.1	3.3–4.7

	5.0	6.0	7.0	8.0	9.0	10.0	12.0	15.0	20.0
2	.6–9.4	1.1–10.9	1.4–12.6	1.7–14.3	2.0–16.0	2.7–17.3	2.9–21.1	3.8–26.2	5.7–34.3
3	1.4–8.6	2.0–10.0	2.5–11.5	3.4–12.6	3.8–14.2	4.3–15.7	5.3–18.7	7.5–22.5	9.5–30.5
4	2.1–7.9	2.8– 9.2	3.4–10.6	4.0–12.0	4.5–13.5	5.1–14.9	6.3–17.7	7.8–22.2	10.9–29.1
5	2.4–7.6	3.1– 8.9	3.8–10.2	4.4–11.6	5.0–13.0	5.6–14.4	6.8–17.2	8.5–21.5	11.8–28.2
6	2.7–7.3	3.4– 8.6	4.1– 9.9	4.7–11.3	5.3–12.7	6.0–14.0	7.2–16.8	9.1–20.9	12.6–27.4
7	2.9–7.1	3.6– 8.4	4.3– 9.7	5.0–11.0	5.6–12.4	6.3–13.7	7.6–16.4	9.6–20.4	13.2–26.8
8	3.0–7.0	3.8– 8.2	4.5– 9.5	5.2–10.8	5.9–12.1	6.6–13.4	7.9–16.1	10.0–20.0	13.6–26.4
9	3.1–6.9	3.9– 8.1	4.6– 9.4	5.3–10.7	6.0–12.0	6.7–13.3	8.1–15.9	10.2–19.8	13.9–26.1
10	3.2–6.8	4.0– 8.0	4.7– 9.3	5.4–10.6	6.2–11.8	6.9–13.1	8.3–15.7	10.4–19.6	14.2–25.8
12	3.3–6.7	4.2– 7.8	4.9– 9.1	5.6–10.4	6.4–11.6	7.1–12.9	8.6–15.4	10.8–19.2	14.7–25.3
15	3.5–6.5	4.4– 7.6	5.2– 8.8	5.9–10.1	6.7–11.3	7.5–12.5	9.0–15.0	11.3–18.7	15.3–24.7
20	3.7–6.3	4.6– 7.4	5.4– 8.6	6.2– 9.8	6.9–11.1	7.8–12.2	9.4–14.6	11.8–18.2	15.9–24.1
30	4.0–6.0	4.8– 7.2	5.7– 8.3	6.5– 9.5	7.4–10.6	8.2–11.8	9.9–14.1	12.4–17.6	16.7–23.3
40	4.1–5.9	5.0– 7.0	5.9– 8.1	6.7– 9.3	7.6–10.4	8.5–11.5	10.2–13.8	12.7–17.3	17.1–22.9
50	4.2–5.8	5.1– 6.9	6.0– 8.0	6.9– 9.1	7.7–10.3	8.6–11.4	10.3–13.7	13.0–17.0	17.4–22.6

various sizes at the 80+ percent probability level assuming that such means are subject to the same magnitude of error as the actual catches in Table 1. For instance, Table 2 shows that a lake with a "true" catch mean of 2 perch per set is apt, at least 80 percent of the time, to yield mean perch catches of 10-set combinations ranging between 1.2 and 2.8 fish.

The construction of Table 2 can be best understood by an examination of the catch distributions in Table 1. First, it will be noted that in Table 1 the standard deviation approximates the mean in size where the means of the series are small, but that the ratio of the standard deviation to the mean decreases as the size of the mean catch increases. This relationship was plotted and a curve drawn. From this curve the smoothed or average ratios (R) were estimated. The first figure in each of the following pairs is the mean catch and the second figure is the ratio of the standard deviation to the mean for means of that particular size: less than 2/1.1; 3/1.0; 4/.97; 5/.95; 6/.88; 7/.85; 8/.84; 9/.83; 10/.82; 12/.81; 15/.80; 20/.76; 30/.73; 40/.68; and 50/.62.

In a normally distributed population, if the mean and standard deviation are the same size, the range which would include 80 percent of the items could be expressed as the mean ±1.2 times the mean (equivalent to 1.2 standard deviations). Error associated with means of such series at the 80 percent probability level could also be expressed in terms of the mean by dividing the quantity, 1.2 times the mean, by the square root of the number of items in the series.

However, as has been noted in the discussion of the catch data in Table 1, the dispersion of the catches, as shown by standard deviation, tends to increase as the size of the mean decreases—this relationship probably reflecting the associative behavior of fishes. Therefore, if catch error is to be expressed in terms of the mean, correction must be made for this relationship. Such correction is attempted in the following formula which expresses the catch error, at the 80+ percent probability level, associated with means of series such as those in Table 1.

$$\text{Netting Error} = \mathrm{X} \pm \frac{1.2\,\overline{\mathrm{X}}\,\mathrm{R}}{\sqrt{\mathrm{N}}}$$

Where

$\overline{X}$ = Mean catch of a series of net sets.
N = Number of sets in the series.
R = Ratio of standard deviation to mean for mean of a particular size as found from data in Table 1.

Using this formula the confidence limits or ranges of error given in Table 2 were calculated. For example, the range that could be expected to include at least 80 percent of the means of combinations of 10 net sets in a lake which has a theoretical true mean catch of 4 fish in 10 sets, was calculated as 4± the quantity 4(1.2) over the square root of

10, times 0.97. This gives the confidence range 2.5 to 5.5 fish shown in Table 2 for 4 fish in 10 sets.

Because Table 2 is derived from Table 1 the confidence limits calculated by the above formula can be expected to apply only to catches from waters in which the distribution of catches can be expected to be similar to the series in Table 1. Application of Table 2 is best illustrated by problems.

Problem 3.—Is there an 80 percent chance that a mean catch of 4.0 pikeperch in 6 sets represents a population larger than that which might be represented by the state-wide average catch of 2.0 pike-perch per set? *Proposed solution.* It will be observed from Table 2 that the odds are better than 80 percent that a mean catch of 4.0 pikeperch in 6 sets will not come from populations having true catch means smaller than 2.5 or larger than 7.0 fish. Since 2.5 is larger than 2.0, the state-wide average (here considered to be a "true" mean), the chances are somewhat better than 80 percent that the catch considered represents a population larger than that which might be represented by the state-wide average.

Problem 4.—Is there an 80 percent chance that a mean catch of 5.0 pike-perch in 9 sets represents a population larger than that from which a mean catch of 4.0 pike-perch in 7 sets might come? *Proposed solution.* Proceding as before it will be found from Table 2 that there is at least an 80 percent chance that a catch of 5 pikeperch in 9 sets does not come from populations having true catch means smaller than 3.5 or larger than 8.0 fish. Similar limits for a catch of 4 pikeperch in 7 sets are 2.5 to 7.0. Since these ranges overlap the chances are less than 80 percent that these catches indicate populations of different sizes.

CONCLUSION

The foregoing considerations and calculations are not presented as a general and final solution to the problem of netting error. Rather, they represent an approach to a problem which is of great interest and importance to northern fisheries workers. The confidence limits given in Table 2 can be considered to be only proximate and to be applicable only to summer gill-net catches of perch, pike, and pikeperch in Minnesota lakes or other waters where the catch distribution can be expected to be similar to that shown in Table 1. Also sampling must be done in the same way as it was done in obtaining these series.

In conclusion, the writer wishes to thank the members of the Fisheries Research Unit who supplied the data and offered many helpful comments during the preparation of the paper. The writer is also very grateful to several fishery workers of other states who read and commented upon the earlier drafts of this paper. Since the interpretation of gill-net catches is controversial, the writer wishes to make clear, that although aid is gratefully acknowledged, he alone is responsible for the foregoing approach to the problem of netting error.

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STRATIFIED SUBSAMPLING FOR DETERMINING AGE DISTRIBUTIONS

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Abstract

Effective age composition studies in large fisheries demand sampling of very large numbers of fish. Establishment of a practical program of investigation calls for measures which reduce the actual age determination to a point where it can be conveniently handled. A method is described whereby age composition is determined from a large number of length measurements using a relatively small number of age determinations. The procedure is an independent modification of one suggested by Fridriksson in 1934 and is an improvement in that it gives more accurate results for those age groups at the extremities of the distribution. Samples of a Pacific coast flounder have been drawn upon to demonstrate the reliability of the method for various types of size distribution and for various levels in the intensity of age sampling.

Introduction

In the investigation of large fisheries the effective study of age composition in the various populations necessitates the sampling of very large numbers of fish. Because age determination is a time-consuming process, it is not uncommon to find the field data accumulating far more quickly than they can be conveniently handled in the laboratory. In certain instances it might be possible to alleviate this congestion by reducing the number of incoming samples, but more often this would prove inadvisable in the light of the knowledge or at least the suspicion that the fishery is operating on populations engaged in complex movements from ground to ground. The problem arises of devising a means whereby the age analysis may be accelerated without a reduction in the number of samples.

The purpose of this paper is to demonstrate and test a means of calculating age distributions using a large number of length measurements and a relatively small number of age determinations.

Method

Fridriksson (1934) was confronted with this problem in his study of the cod of the north Atlantic. He suggested a method of calculating the age distribution of a large number of measured fish by means of a numerically small sample of otolith determinations. The method is essentially one involving the examination of a straight subsample of a large sample of measured individuals. However, stratified subsampling, as proposed here, is a modification which gives improved representation

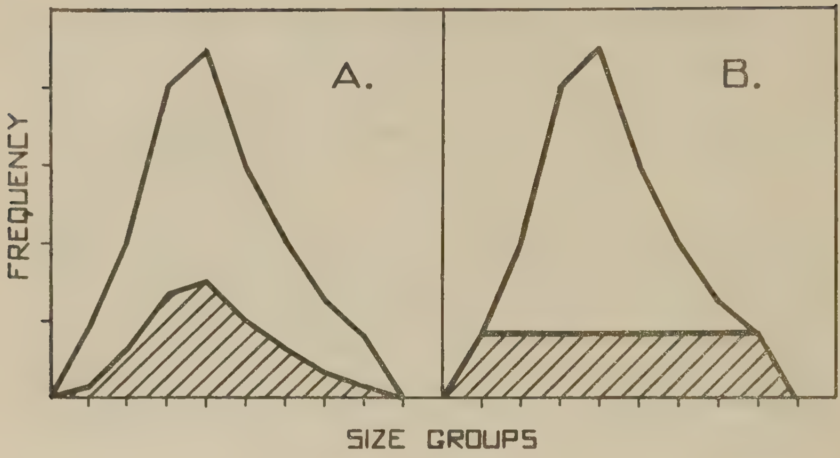

FIGURE 1.—Length frequency polygons illustrating the difference between the method of subsampling proposed by Fridriksson (A) and that of stratified subsampling (B). The subsamples are indicated by the shaded areas.

to the more weakly represented size groups. The difference between the two methods is illustrated in Figure 1.

In stratified subsampling the same number of scale or otolith samples is examined from each size group, the number depending upon the frequency level chosen for the subsample. If the class frequency is below this level in the outlying size groups, all available individuals are examined. Calculations of age distributions based on this procedure will tend to be more accurate for those age groups at the extremities of the distribution. Furthermore, a stratified subsample of age determinations is of more general use than the type proposed by Fridriksson in that it gives much more satisfactory results in studies of growth rates. There is less tendency to have more individuals than necessary in the well represented size groups and too few in the poorly represented ones.

The basic assumption behind any experiment in subsampling is that the number of individuals in any age group found in a particular size class in the subsample is proportional to the number of individuals of that age group and size, in the sample. Thus, if five 3-year-olds are found in a subsample of 10 from a sample of 30 in a given size class, the number of 3-year-olds in the sample is 5/10 x 30 or 15.

A simple hypothetical case is given in Table 1 to demonstrate the calculation of the age distribution in a large sample (Y) from a subsample (X) which has been stratified at 10 individuals in each size class. In the case of fish of lengths 30 and 34 centimeters, there are 10 or less individuals in the entire sample. Clearly, since Y = X then the calculated distribution at those lengths is the same as the actual distribution.

TABLE 1.—*An hypothetical example of the determination of the age distribution in a sample (Y) from a stratified subsample (X).*

Size Class	Subsample X	Age groups in X				Sample Y	Calculated age groups in Y			
		III	IV	V	VI		III	IV	V	VI
30	10	7	2	1	...	10	7	2	1	...
31	10	3	5	2	...	20	6	10	4	...
32	10	1	6	2	1	40	4	24	8	4
33	10	...	2	7	1	20	...	4	14	2
34	3	...	...	1	2	3	...	...	1	2

MATERIALS

The results of age composition studies being conducted by the Pacific Biological Station on one of the Pacific coast flounders, *Parophrys vetulus,* have been drawn upon to test the applicability of the method of stratified subsampling for determining age distributions. The material lends itself to the study for several reasons.

(1) The diversity of types of length frequency polygon to which tests may be applied is wide.

(2) Age analyses of *Parophrys vetulus* have revealed that there is considerable variation in the growth rates within particular populations. Consequently it is common to find many age groups represented in any one size class, or conversely, there is a considerable range of sizes at any one age. Accordingly, deficiencies in the method will more likely be evident in this case than in those cases where the size variations within age groups are not so great.

(3) Age determinations of this species are made from otoliths. Upon being collected the left-hand otoliths of all fish are stored in a shell vial, separated according to size class by heavy paper dividers. In preparation for reading, the otoliths in each compartment are removed at random, one by one, and age determinations are recorded in order under identifying serial numbers. The random manner in which the otoliths are examined makes it possible to set up and study the effects of various levels of stratified subsampling wherever suitably large samples are available.

The examples used range in size from 300 to 375 individuals per sample. This is approximately the maximum size which can be conveniently handled under ordinary field conditions.

In each example three levels of stratified subsampling have been tested, namely class frequencies of 5, 10, and 15. Tests of association between expected and calculated distributions have been made by means of the Chi-square test.

RESULTS OF SUBSAMPLING

The first example involves a frequency polygon exhibiting a narrow range of sizes and a very sharp mode (Figure 2). The actual age

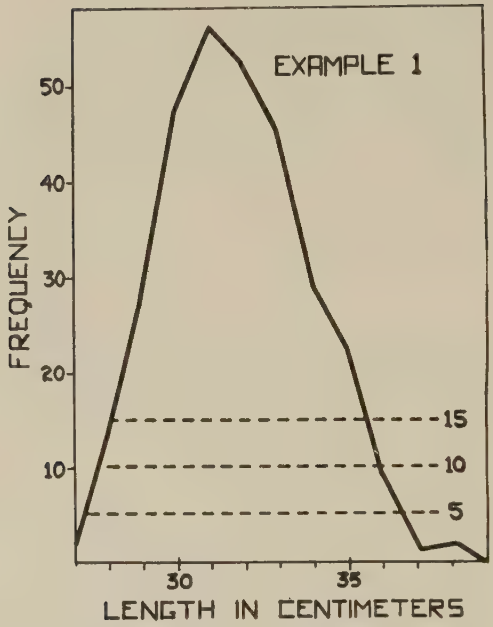

FIGURE 2.—Length frequency polygon of *Parophrys vetulus* showing three levels of stratified subsampling where sample has narrow range of sizes.

distribution in this polygon and the calculated distributions as obtained from the three levels of stratified subsampling are given in example 1 (Table 2). The probability values corresponding to the values of X^2 obtained for the three subsample calculations were less than .01, .50 — .30, and .50 — .30, respectively, for the three levels of stratification, 5, 10, and 15. The difference between the calculated and expected distributions is highly significant at the 5 level but is not significant at either level 10 or 15.

In contrast to the frequency polygon in Figure 2 are examples 2 and 3 in Figure 3. The modes are sharp but the size range is doubled. The calculated and expected age distributions as obtained from these data are given in examples 2 and 3 of Table 2. The results of example 2 at the three levels of subsampling 5, 10, and 15 give probability values of 0.05 — 0.02, 0.30 — 0.20, and 0.70 — 0.50, respectively. Once again the age distribution as calculated from the subsampling level of five individuals differs significantly from the actual distribution, while those calculated from higher levels do not. The corresponding probability values for the Chi-squares in example 3 at levels 5, 10, and 15 are 0.50 — 0.30, 0.70 — 0.50, and 0.80 — 0.70, respectively. In this case the association is much closer, and even at the lower level of subsampling the difference is not significant.

TABLE 2.—*A comparison of the calculated and actual age distributions in the examples illustrated in Figures 2 and 3 with* X^2 *and* p *values for three levels of stratified subsampling.*

Example	Sampling level	Age groups										Total	X^2	p
		III	IV	V	VI	VII	VIII	IX	X	XI	XII			
1	Actual	....	38	70	90	63	36	9	....	....	....	306		
	Level 5	....	24.6	57.8	106.6	68.4	45.8	1.8	....	....	....	306	18.81	0.01
	Level 10	....	28.0	76.5	96.4	65.6	34.0	5.5	....	....	....	306	5.23	0.50–0.30
	Level 15	....	32.3	64.5	100.6	59.4	33.2	5.4	....	....	....	306	4.44	0.50–0.30
2	Actual	13	27	43	54	64	51	48	33	11	9	353		
	Level 5	12.2	23.8	31.0	66.0	51.6	68.0	42.0	38.0	15.2	5.2	353	19.23	0.05–0.02
	Level 10	13.0	24.8	33.4	60.3	63.0	53.6	36.4	44.4	12.7	7.3	353	10.87	0.30–0.20
	Level 15	13.0	25.4	42.4	58.6	57.3	53.9	35.5	38.0	13.9	10.8	353	6.48	0.70–0.50
3	Actual	57	142	70	37	31	11	8	10	....	....	366		
	Level 5	45.8	160.4	64.4	32.4	35.4	11.8	5.4	10.4	....	....	366	7.13	0.50–0.30
	Level 10	52.5	155.0	66.7	28.9	36.4	10.5	6.0	10.0	....	....	366	4.94	0.70–0.50
	Level 15	60.9	150.0	63.8	29.6	36.0	10.0	6.0	10.0	....	....	366	4.15	0.80–0.70
4	Actual	58	64	62	40	52	40	23	15	4	....	358		
	Level 5	40.2	80.6	94.0	26.2	51.6	39.4	22.0	3.0	1.0	....	358	42.54	0.01
	Level 10	50.8	68.6	77.2	28.3	37.5	50.6	23.0	13.7	4.9	....	358	15.53	0.05
	Level 15	53.1	69.7	74.1	32.2	44.2	45.5	23.0	14.6	4.9	....	358	6.97	0.70–0.50
5	Actual	27	66	38	53	58	52	36	25	15	5	375		
	Level 5	31.0	65.4	24.4	28.0	75.0	70.6	40.2	20.0	15.8	4.6	375	30.44	0.01
	Level 10	26.3	69.2	38.2	31.5	63.5	58.6	44.4	25.0	14.0	4.3	375	12.36	0.20–0.10
	Level 15	27.4	67.6	37.0	45.1	54.5	54.5	45.1	27.3	12.3	4.2	375	4.97	0.90–0.80

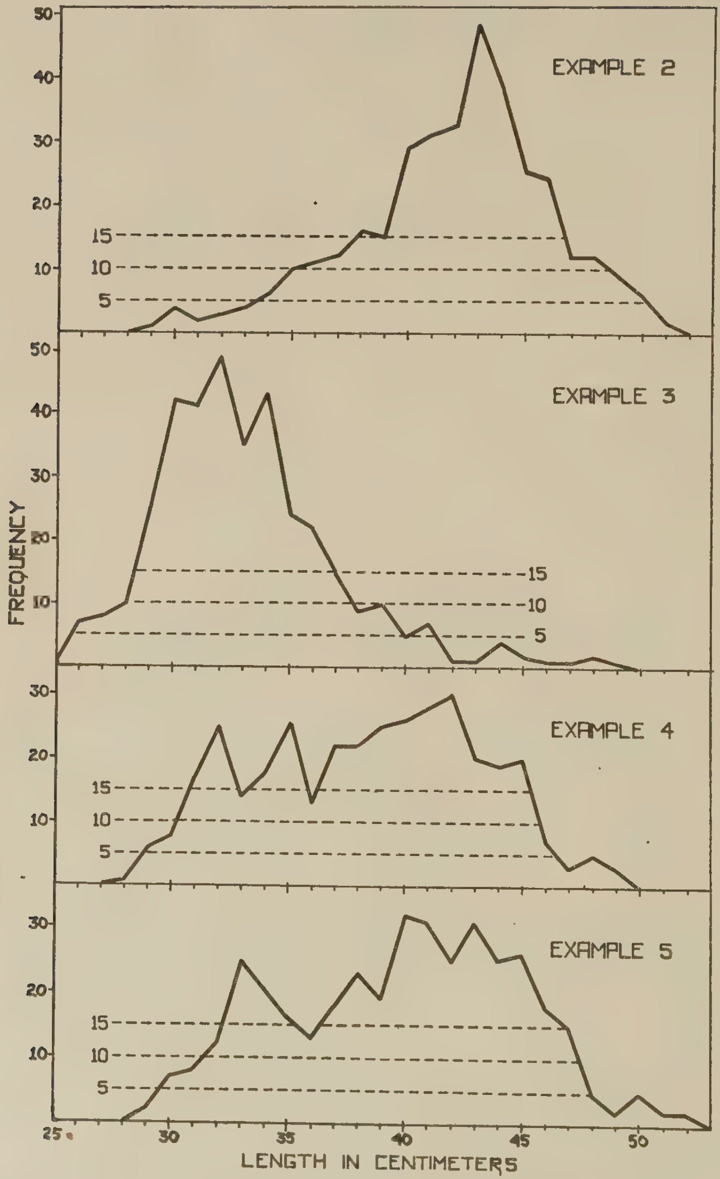

FIGURE 3.—Length frequency polygons of *Parophrys vetulus* showing three levels of stratified subsampling where samples are uni- and poly-modal and cover a wide range of sizes.

Another type of length frequency polygon which is frequently encountered in samples of *Parophrys vetulus* is one in which the distribution is bi- or poly-modal or irregular in shape even after fairly heavy sampling. Such occurrences are often the effect of fluctuations in the success of year classes or the effect of heterogeneity in the distribution of the fish on the grounds. Two such examples are shown in examples 4 and 5 of Figure 3. The calculation of the age distributions from subsamples of these data is given in table 2.

In example 4 it was found that the probability values for the age distributions calculated from the three levels of subsampling were less than .01, .05, and .70 — .50. As in several of the previous examples the difference between the expected distribution and the one calculated from the 5 level is highly significant. At the 10 level in this case there is doubt as to whether the results are not significantly different.

In example 5 the *p* values are somewhat higher, being less than .01, .20 — .10, and .90 — .80 for the levels 5, 10, and 15, respectively. Only in the distribution calculated from the 5 level is the difference significant.

DISCUSSION

From the above results it has been shown that there is considerable variation in the probability values for distributions calculated from any given level of subsampling. Clearly, the subsampling level of five individuals is unsatisfactory, since the differences between the calculated and actual distributions were in most cases highly significant. If any one level of stratification is to be decided upon and applied to all samples taken from the fishery then it would be advisable to adopt the 15 level. However, under certain conditions, namely when the frequency polygon is sharply uni-modal, the 10 level could be adopted with considerable reliability. In the event that two standards of subsampling are established it would be necessary to collect sufficient data in the field to allow for a possible decision at the time of analysis as to whether or not the subsampling level should be raised from 10 to 15.

With respect to *Parophrys vetulus*, whatever procedure is adopted, whether it be the standard of 15 for all samples or 10 and 15 depending on the character of the frequency polygon, there will be a substantial reduction in the number of age determinations. In the first example (Figure 2) a stratified subsample with a class frequency of 10 amounts to 29 percent of the sample. In the second and third examples (Figure 3) the subsample at the same level is about 47 percent in both cases. The subsamples in the last two examples (Figure 3, examples 4 and 5) amount to approximately 50 percent at the 10 level and 70 percent at the more desirable 15 level. Considering the time required for accurate age composition studies even a 30 percent reduction in labor would be well worthwhile.

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THE PHILIPPINE INSTITUTE OF FISHERIES TECHNOLOGY: ITS ORGANIZATION AND PROGRESS

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Abstract

The history, organization, and functions of the Philippine Institute of Fisheries Technology are outlined. The requirements for admission, courses offered, and facilities for instruction and research are discussed. The investigations being pursued and the services rendered to the public are enumerated.

Introduction

Training of Filipino fishermen in efficient fishing methods and in wise utilization of fishery resources was proposed by the Philippine Government long before the outbreak of the last war. It was not until the early part of 1941 that this proposal received favorable consideration in the Philippine Congress, which then authorized the creation of a school of fisheries. Plans were drawn and preparations were made to open the school in July, 1942, but due to the outbreak of the war in December, 1941, the project was suspended indefinitely.

During the Japanese occupation of the Philippines, the National Assembly appropriated 400,000 pesos[1] for a school of fisheries which was opened at Navotas, Rizal, on July 1, 1944. It lasted for about 2½ months and then was forced to close because conditions were too uncertain to continue operations.

With the re-establishment of the Commonwealth Government of the Philippines after liberation, an appropriation for a school of fisheries was made available. The release of 255,380 pesos out of the 333,000 pesos allotted under a special budget was approved by the President of the Philippines in January, 1946. This action made possible the opening on July 1, 1946, of the Philippine Institute of Fisheries Technology at Navotas, Rizal. Since then a regular annual appropriation of 400,000 pesos has been included in the national budget. In June, 1949, the Institute was moved to Manila to accommodate the increased enrollment.

Organization

The Philippine Institute of Fisheries Technology is under the supervision of the Secretary of Agriculture and Natural Resources through the Director of the Bureau of Fisheries. Its administration, however, rests with its administrative officers. Originally designed as a service training school, its activities have been expanded to include research and extension service. The functions are carried out through the following sections: (1) General Administration, (2) Fish Capture, (3) Fish Preservation, (4) Fish Culture, (5) Fishery Biology, (6) Fishery Engineering, (7) Chemistry, and (8) Fishery Economics.

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[1] Two Philippine pesos are equivalent to one United States dollar.

INSTRUCTION

Object of Instruction.—The aim is to turn out graduates who have adequate knowledge of up-to-date and efficient methods of the utilization of fishery resources; who know the principles of fishery conservation and the value of their application in productive activities; and who are prepared to step immediately into their chosen phase of fisheries industry or further their studies in other institutions to acquire sufficient background for research.

Requirements for Admission.—Only students who have finished high school are admitted to the regular courses. Written competitive examinations are given each year and the new students enrolled are selected from among those who have passed with the highest grades.

Facilities for Instruction.—The Institute now occupies the former Library Building of the University of the Philippines in Manila. This three-story building provides adequate space for offices, classrooms, laboratories, and the library. Laboratory equipment has been acquired through purchase out of the annual appropriation and through transfer of surplus war materials turned over to the Philippine Government by the U. S. Army. A combination machine, carpentry, and blacksmithing shop has been set up for instruction in marine machinery and in handling iron and wood-working tools. Two fishing boats, each 45 feet long and equipped with fishing gear and navigation instruments, are used for instruction in in-shore fishing. A training ship about 103 feet long, which can accommodate 30 students on board aside from the regular members of the crew, was recently acquired for instruction in off-shore fishing and oceanographic research. Construction of a pilot canning plant is already underway and the machinery has been purchased.

The experimental fish farms of the Bureau of Fisheries are used in the training of students in fish culture. These fish farms are: (1) the Dagatdagatan Salt-Water Experiment Station at Navotas, Rizal, where the cultivation of marine fishes is carried out; (2) the Limnological Station at Tanay, Rizal, where limnological studies and the propagation of fresh-water fishes are undertaken; and (3) the Oyster Farm at Binakayan, Cavite, where the cultivation of oysters and other mollusks is conducted.

The library of the Institute is being built up by purchasing books and subscribing to fishery journals. Free publications are received from other institutions and as donations from private individuals. The Institute, however, is still handicapped by the lack of much needed references.

Courses of Instruction.—Three regular courses are offered: Fish Capture, Fish Culture, and Fish Preservation, each extending over a period of 2½ years. The first semester, common to all, and intended to introduce the students to the subject matter to be taken up later and to guide them in the selection of the course they will pursue, provides instruction in the fundamentals of zoology, botany, chemistry, and fishery resources, and in the national language, especially Tagalog grammar and Tagalog fishery vocabulary. Aquatic zoology and botany, meteorology, fishery economics and fishery laws, and, during the first summer, trigonometry, shop work, and swimming and boating are required of all students.

In the main, however, after the first semester each student specializes in the subjects related and essential to mastery of his selected phase of the fishing industry. The following courses are offered:

Fish Capture Course.—Marine machinery, fish boat construction, seamanship, navigation, oceanography, and several courses in fish capture.

Fish Preservation Courses.—Analytical and organic chemistry, bacteriology, and numerous courses in fish preservation.

Fish Culture Course.—Analytical chemistry including analysis of water and of fish foods, limnology, plane surveying, fish-pond engineering, and several courses in fish culture and fish diseases.

The foregoing courses are completed by the end of the second year, and after them the students spend 6 months of intensive practice in the application of the principles they have learned. Those in the Fish Capture Course take practical training in pelagic and demersal fishing; those in the Fish Preservation Course work in salting, drying, smoking, refrigeration, cold storage, and canning of fish; and those in the Fish Culture Course do practical work in fish propagation, and fresh-water and marine fish cultivation.

The Philippine Fishery Program of the U. S. Fish and Wildlife Service has afforded excellent opportunities during the last few years for the practical training of the students of the Institute. A great many of them have been given on-the-job training in biological, oceanographic, and technological research. Others have been recipients of training grants, authorized in the Philippine Rehabilitation Act and awarded through competitive examination, which provides for 1 year of training in the United States in methods of deep-sea fishing and in other fields necessary to the development of the Philippine fisheries. Of the 125 grants authorized in the Act, 75 went to students of the Institute.

Enrollment.—The enrollment since 1946 has totalled 462. At this writing, only the first class has had time to finish the full course and the 6 months of practical training; of the 99 who entered 68 graduated. Break-down by courses shows that over 50 percent of all students have chosen Fish Capture, with the remainder fairly evenly divided between Fish Culture and Fish Preservation.

RESEARCH

Research is at present being carried on by members of the faculty along the following lines: (1) biological—including studies of the biology of the important commercial fishes, fish productivity in various waters, and the protection of the fishery resources; (2) technological—including studies on the improvement and development of methods in the utilization of the fishery resources, as well as the standardization of the fishery products; and (3) economic—including a survey of the living conditions of the fishermen, and the factors of production and marketing of the fishery products.

EXTENSION SERVICE

Service is rendered to the general public in the following ways: (1) by giving lectures and demonstrations to fishermen of the different methods of catching fish, of preserving and processing fishery products, and of the proper methods of cultivation of fish in ponds; (2) by giving technical assistance to investors in starting fishery business; (3) by aiding fishermen in solving their fishery problems; and (4) by preparing fishery bulletins and leaflets for distribution.

The necessity of training Filipino fishermen in the scientific methods of utilizing fishery resources is fast gaining recognition. Two regional schools, the Catbalogan School of Fisheries at Samar and the Tabacco School of Fisheries at Albay, to be operated under the Bureau of Fisheries through the Philippine Institute of Fisheries Technology, have already been approved by the Philippine Congress, and requests for the establishment of more vocational fishery schools in the different fishing districts are receiving encouragement. Plans are also drawn to raise the standard of instruction in the Philippine Institute of Fisheries Technology and to make it the center for advanced training and research in the Philippines.

RADIOACTIVE WASTES AND THEIR SIGNIFICANCE IN STREAM ECOLOGY

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Abstract

The problem of devising safe means for the disposal of radioactive wastes has long concerned the United States Atomic Energy Commission but no completely satisfactory solution has been found. The nature and sources of such wastes and methods of handling are reviewed.

Aquatic organisms, perhaps more than any other group of organisms, are directly exposed to radiation hazard from the wastes of atomic energy operations and may be subjected to long-continued low-level exposure. The effect on organisms of such low-level radiation, as a feature of the relatively constant environment, has received very little study owing, in part, to the difficulties of experimental observation.

A tributary of the Clinch River, Tennessee drainage, which has been receiving minor quantities of radioactive wastes for some time and which contains an apparently normal flora and fauna including abundant plankton and a mixed warm-water fish population has been selected for ecological study. Adjacent waters of the Tennessee drainage are unpolluted and, therefore, offer suitable areas for the comparison of conditions of life in contaminated waters. The principal problems to be investigated and the methods of ecological study, including quantitative changes in population-composition and density, are outlined and progress in initiating the study is described. Radiation from radioactive wastes is a new element in the ecology of some streams which must be taken into account.

Introduction

The Atomic Energy Commission in January, 1949, sponsored a seminar on the subject of Safe Disposal of Radioactive Wastes before a select group of Public Health officers and sanitary engineers from all sections of the country. In his introductory remarks, David E. Lilienthal, Chairman of the Atomic Energy Commission, stated:

> Some industrial wastes have been handled well at the outset but in many industries the problems associated with waste disposal have not been handled well at the outset. It is our earnest desire . . . to have this phase of our responsibilities well handled—as well as technical skill and energy and foresight at this stage can handle it . . .
>
> The waste disposal problem is a part of this general business of learning how to live with radiation . . .
>
> Radiation is just as much a natural phenomenon as anything else. The fact that we have multiplied it by intelligence does not change that fact . . . But I am sure also that just as we were able by our intelligence to conquer other things, we will conquer this as well . . . (Lilienthal, 1949).

The fission process, by which plutonium is produced in the great reactors or atomic furnaces of the Atomic Energy Commission, yields a great variety of products which are highly radioactive. Only a few of these can be used at the present time and the rest must be discarded where they can do no harm. The radiations from the radioisotopes of various elements are all different but they are able to penetrate solid matter to a greater or lesser degree. They all produce ionization in the molecules of the medium through which they pass and they all have definite detrimental effects on living tissues.[1] Since some of these isotopes will continue to give off radiation for thousands of years, regardless of any chemical or physical treatment, the problem of safe handling is thus presented.

At first sight, we are faced with a puzzling situation. Although penetrating radiations admittedly are harmful to all organisms, we have been living successfully with these radiations for a thousand centuries. Cosmic rays, the most penetrating type of radiation, pervade the universe. They are more powerful than the most energetic gamma rays. Traces of radium and other naturally radioactive elements are found in most soils and rocks and are present in minute amounts in our own bodies. Radioactivity from radon, a decay product of radium, is present in readily detectable amounts in mineral springs, the water of which is prized for human consumption. Water taken from such springs in Colorado, Indiana, Missouri, Ohio, New York, Texas, and Virginia has been tested and in every case the radioactive radon content is as high or higher than that of the Clinch River which has been receiving drainage from the Oak Ridge atomic energy plant for more than 5 years. The natural radon and thoron activity in the air of the Knoxville area is about 3×10^{-10} microcurie per cubic centimeter which is roughly equivalent to the activity of the air in the vicinity of a great atomic energy installation (Morgan, 1949).

The Atomic Energy Commission makes the proud boast and proves it with careful records that the health level of its thousands of employees, working even in the vicinity of atomic piles and in the great chemical plants where radiation equivalent to that produced by tons of radium is continuously present, is better than the health level of employees in any other great industry in the United States. Obviously, effective measures for protecting human health against radiation have been worked out and applied on a large scale.

Why, then, are we so much concerned with the exposure of wild animals to these rays? Before we can answer this question it is necessary to consider the sources and nature of radioactive wastes, the methods used in their treatment, the chances that wildlife species will encounter them, and the effects on these animals if they are exposed.

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[1] At the annual meeting of the American Fisheries Society in 1948, I attempted to explain the nature and origin of atomic radiations and their effects on living organisms. For the convenience of the reader, I am presenting as an appendix to this paper some background information about radioactivity, units for measuring radiation and possible limits of exposure.

SOURCES AND NATURE OF RADIOACTIVE WASTES

Radioactive wastes originate in the reactors or atomic piles of the great manufacturing plants of the Atomic Energy Commission such as those at Oak Ridge, Tennessee, and Hanford, Washington. When uranium metal placed in the reactor to produce plutonium is bombarded by neutrons, energy is added which produces a state of excitation in the atomic nuclei. In an inconceivably short time the atoms split into two unequal fragments. This is called fission. These fragments of unequal and varying mass are the atoms of more than a score of alkaline and rare earth elements about the middle of the periodic table. They also comprise more than a hundred isotopes of these elements, virtually all of which are radioactive. The radioactivity of this complex group of fission products varies in the type of rays emitted, in their energy of emission and range of penetration, and in the length of their radioactive half-lives. The majority of the fission products have high activities but short or very short half-lives ranging from micro-seconds to some 40 days. Moreover, the quantities of individual isotopes produced by fission in the reactor also vary enormously from a few hundred thousandths of one percent to about six percent of the total yield (Lapp and Andrews, 1948; U. S. Air Force Air Materiel Command, 1948). Thus, the products of plutonium manufacture are tremendously complex but only a few of them can be used at the present time and all the rest must be discarded.

The great separation plants associated with the reactors where plutonium and other useful products are concentrated and extracted likewise produce large quantities of radioactive wastes such as above described. Radioactivity from the separation plants, however, is controlled and reduced by permitting the short-lived fission products to undergo radioactive decay for some time before processing the uranium metal from the piles.

In addition to waste from the manufacture of plutonium, a great many elements are irradiated in reactors or cyclotrons to produce the isotopes now so widely distributed by the Atomic Energy Commission for research purposes. The concentration, extraction, and purification of these isotopes likewise contribute to the variety and quantity of radioactive wastes. Finally, these isotopes, now used for a number of industrial purposes and for an extensive program of physical, agricultural, biological, and medical research in universities and laboratories throughout the country and for treatment of diseases in hospitals, eventually contribute their share to the problems of radioactive waste disposal (Atomic Energy Commission, 1949a). These wastes may be highly concentrated or vastly dilute. They exist in solid, liquid, or gaseous form. In terms of their radioactivity, they may be highly energetic or they may be nearly inert. In terms of physical quantity, however, they are usually small in mass and may exist in only the slightest traces in high dilutions.

WASTE DISPOSAL METHODS

There are four principal methods of radioactive waste disposal used by the Atomic Energy Commission and its subsidiaries. These are: (1) air dilution, (2) water and mud dilution, (3) storage and shipping, and (4) burial. It is the responsibility of the Atomic Energy Commission, discharged by the Health Physics organizations at each of its operating centers, to make certain that these wastes are disposed of in a safe manner.

Air Dilution.—Reactors of the Atomic Energy Commission such as those at Oak Ridge and the new Brookhaven Laboratory are cooled by vast quantities of filtered air which is then forced out of stacks some 200 to 300 feet high. Radioactive argon, which has a half-life of 110 minutes, is produced in the cooling air and together with traces of iodine and various other radioactive substances is distributed into the atmosphere. These radioactive gases are so diluted by wind currents that the air normally reaches a tolerance concentration at a distance of less than 200 feet from the top of the stacks (Morgan, 1949). In addition to careful and extensive monitoring of the air with automatic recording meters in the vicinity of the establishment, elaborate studies of meteorology are made and if it is found that temperature inversions in the air strata surrounding the stack or conditions of turbulence would tend to bring the radioactive gases toward the earth, pile operations are reduced or completely stopped until safe disposal in the air is again possible (Beers, 1949).

Some of the solid radioactive products suspended in the air reach the ground in quantities which tend to build up before each rain to a few times the natural background of radiation but the total air and surface activity in the neighborhood of the Oak Ridge National Laboratory, for example, seldom exceeds a few one-thousandths of the tolerance value. Air dilution therefore appears to be a safe method of disposal for those wastes which are primarily gaseous and no hazard to human health or to terrestrial wildlife exists under normal practices.

Water and Mud Dilution.—At the present time, cooling liquids from the reactors containing low-level radioactivity and certain radiochemical laboratory wastes are normally discharged in surface waters only after a hold-up period to permit radioactive decay. Much of the activity is taken up by the mud of the settling ponds. After being diluted in surface waters, the activity downstream is rapidly decreased by further adsorption on the minute particles of suspended clay and silt. Thus, the radioactivity is carried down into the bottom and fixed in position, barring unusual flood conditions, until most of the activity has declined to insignificant levels. A special case of "mud dilution" is the discharge of liquid wastes into dry wells in desert areas. Here adsorption on the soil particles binds the activity and prevents its spread.

Storage and Shipping.—Highly radioactive liquid wastes from production processes are concentrated and stored permanently in tanks under ground. Active wastes from laboratories normally are shipped to principal installations of the Atomic Energy Commission where means are provided for proper handling.

Burial.—In addition to underground storage of waste liquids containing alpha-emitting contamination, all active solid materials including contaminated apparatus and machinery which cannot be reclaimed are buried in deep trenches in guarded areas to prevent unauthorized removal. A specialized case of burial, sometimes employed, is burial at sea. Since some of the radioactive products are long-lived and would present health hazards for many thousands of years, they are mixed into blocks of concrete and dropped to the bottom of the ocean where they will never bother anyone.

All these methods of waste disposal are utilized in various atomic energy establishments but as Dr. Morgan says,

> Perhaps none of the presently used methods of waste disposal is completely satisfactory for a large scale operation or on a long time basis . . . It is for this reason that studies of new methods of decontamination and safe disposal now under way are believed to be of considerable importance. Most of the health physicists seem to favor some method of concentrating the radioactive waste products and placing them in permanent storage rather than seeking a maximum dilution. Isotopic dilution is the ideal solution for some of the radioactive isotopes such as iodine, carbon, phosphorus, sodium and hydrogen but it cannot be used for the transuranic elements nor for some of the rare elements (Morgan, 1949, page 302).

Thus, it may be seen that the method of waste disposal by water and mud dilution is quite effective for many wastes but from some points of view is the least satisfactory

The concentration of radioactivity in the bottom deposits of streams may be temporarily effective in restricting the spread of contamination, but floods and stream-bed erosion may destroy this stability at any time and carry the contamination further downstream to be redeposited in slack water areas. Such fixing in bottom muds is comparable to the hold-up period of liquid wastes in impoundments permitting radioactive decay to reduce the activity. However, with a constant input of the longer-lived radioactive isotopes at any point in the stream system the level of activity attained at any downstream point must reach eventual equilibrium between the rate of addition and the rate of removal which is a combination of dilution, decay, transport by water flow, sedimentation, and renewed erosion. Thus, over a period of time, radiation which has reached the equilibrium level at a given point in the stream must move progressively downstream and may eventually reach the ocean.

Exposure of Aquatic Organisms to Radiation

Bearing all these facts in mind, it is concluded that aquatic organisms in some streams are more likely to be exposed to the hazards of radiation than are terrestrial animals. They are exposed to the same dangers of absorbing radioactive materials by "inhalation" and ingestion as are terrestrial animals and in addition they are exposed to radiation from the water itself by complete immersion in the radioactive source — a hazard which is extremely limited for land animals. Moreover, from the very nature of atomic energy operations and applications, the exposure of aquatic organisms even to minute amounts of radiation must be more constant and must continue over indefinitely long periods as compared with the more casual and temporary exposure of land animals to airborne contamination. Certainly aquatic animals cannot escape from an environment which is contaminated.

While the sources of radioactive contamination of water are limited in number at the present time, there is no way of foretelling in these early years of the atomic era how widely distributed and generally used these radioisotopes will be in industry and agriculture and clinical medicine in the future.

The bright side of this picture for aquatic life in any stream receiving radioactive wastes from Atomic Energy Commission installations is that the activity in the water downstream from point of discharge is held at very low levels. The announced criterion of the effectiveness of radioactive waste disposal in public waters provides that the water of the stream must be safe for fish to swim in continually and must have such a low level of radioactivity that a person could use it as a sole source of drinking water indefinitely without undergoing radiation damage. It is the aim of the Atomic Energy Commission, by no means attained but vigorously pursued, to devise procedures in the plutonium plants which will operate as closed systems and which will not permit any activity whatever to enter public waters.

An example of the degree of effectiveness of waste disposal practices and the extent to which the aim is approached may be given for the

TABLE 1.—*Ratios of activities of some radioisotopes to the maximum permissible values for ingestion and submersion, for different elapsed times since removal of uranium from the pile.*

Element	Time Since Removal (days)					
	0		100		730	
	Ingestion	Submersion	Ingestion	Submersion	Ingestion	Submersion
Sr^{89}	72	106	19	29	0.005	0.007
Sr^{90}—Y^{90}*	5.7	0.41	5.5	0.40	5.3	0.38
Zr^{95}—Cb^{95}*	0.22	465	0.10	214	0.0001	0.20
I^{131}	44	8.5	0.009	0.0018	....	....
Ba^{140}—La^{140}*	140	274	0.62	1.2	....	....
[1]Pr^{144}	0.000292	72	0.000228	56	0.00005	11

*Values for ingestion depend upon both mother and daughter, while values for submersion depend only on mother.

[1] The value of the ratio for submersion at 100 days for Pr^{144} (fourth column, last line) originally was printed as 5.6 This value was corrected to 56 by Dr. Morgan (personal communication) as shown in the table reproduced above.

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Oak Ridge National Laboratory, the wastes from which drain into White Oak Creek, a tributary of the Clinch River and the Tennessee drainage. Here, the fission products which are not used in the plant operations are held up in tanks and then discharged into settling ponds. The settling pond discharges continuously into the White Oak Creek drainage system which is a series of swamps and small lakes. The storage capacity of the lake can be varied by the addition of flashboards at the dam to increase the hold-up time if necessary. After sedimentation which carries considerable amounts of activity down into the bottom deposits, the waters of White Oak Lake, continuously monitored by means of electrometers and Geiger-Müller counters, discharge into the upper waters of Watts Bar reservoir on the Clinch River where there is a minimum dilution factor of 100.

Table 1 (Morgan, 1949, page 300) lists the ratio of the activity present in these waters to the maximum permissible values (for human consumption) of some of the radioisotopes for different times since removal of a batch of uranium from the pile. As Morgan points out,

> These values should be proportional to the hazard presented by each isotope provided that none of the isotopes is chemically separated or that there is no selective absorption in the clays or by the plant life in the water. However, many of the fission products are selectively absorbed by the plant and animal life in the waste disposal system.

The data in Table 1 indicate that short-lived radioactive elements like 8-day iodine^{131}, 13-day barium^{140}, 40-hour lanthanum^{140}, 65-day zirconium^{95}, and 35-day columbium^{95} present the greatest radiation hazard when the fission products are fresh from the pile. When the material is permitted to decay for a few years as it does in the clay bottom of the stream, 25-year strontium^{90} and 17½-minute praseodymium^{144} present the principal hazards. The dangers of radiation from praseodymium, which has a short half-life and emits energetic beta and soft gamma rays, arise from the fact that it is a decay product of cerium^{144} which has a half-life of 275 days and emits only weak beta rays. It is, therefore, continuously produced for a long time by the cerium, an appre-

TABLE 2.—*Radioactivity [of mud] of White Oak Drainage System*

Location	Approximate Distance Below Settling Pond (Feet)	Activity in April 1945		Activity in October 1946	
		Average per Unit Area (uc/ft.^{2})	Total (c)	Average per Unit Area (uc/ft.^{2})	Total (c)
Marsh	2120	91.5	42.7	145.5	67.8
Intermediate Pond	3250	87.6	4.6	....	....
Mud Flats	6900	22.0	14.9	9.6	6.5
White Oak Lake	8600	8.5	6.8	17.1	13.6
Below Spillway	10350	1.04	0.3	2.7	0.9
Probable Total Activity (c)			69.3		95

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ciable constituent of fission-product wastes. It will be noted that after aging for 2 years the activity from strontium^{90}-yttrium^{90} is only 5.3 times the tolerance value for ingestion and the activity from praseodymium is only 11 times the submersion tolerance. Such activities in the waters of White Oak Creek are reduced to insignificance, so far as human health is concerned, by the great dilution on entering the Clinch River.

Table 2, also taken from Morgan (1949), gives the total radioactivity in the mud in various parts of the White Oak drainage system in April, 1945 and October, 1946 after the Oak Ridge plant had been in operation for several years.

The estimated activity remaining in the mud of the White Oak drainage system in April, 1945, was 13 percent of the total activity that had been discharged into the Creek up to that time but when this figure is corrected for radioactive decay, the retention efficiency is about 70 percent. As Morgan says (1949, p. 301),

> The mud seems to be an efficient remover of all fission products except tellurium. In general, it is believed that a slowly flowing drainage system with a mud bottom is an economical and efficient means of removing fission products from plant waste but it has the disadvantages that flood conditions might suddenly carry the radioactive mud in undesirable quantities beyond the areas of control.

In more recent years improved handling processes have been adopted and it is likely that downstream activity has passed its peak and will continue to decline.

If we assume, because of the long period of active operations at Oak Ridge, that stream pollution conditions there are as extreme as any found at major Atomic Energy Commission installations, it will be seen that any study of the effects of radioactive wastes on aquatic life will be concerned with very low levels of activity which at the worst will present border-line cases of harmful ecological conditions. From the point of view of the protection of human health, waste disposal practices at Oak Ridge are eminently successful. The water of White Oak Creek is "safe to drink." But as conservationists we are concerned with human tolerances for radiation only as they may serve as an index of the unknown tolerances of lesser organisms. We are concerned primarily with the final and long-time effects on animal populations.

Biological Effects of Radiation

If radioisotopes become a constant feature of the environment of aquatic organisms in certain streams they will become available for incorporation into the living tissues either through direct absorption from the water or by entering the food-chain from bacteria to fishes and higher vertebrates. Aquatic organisms, therefore, are directly vulnerable to whatever ill effects may result from both the external and internal radiation which is present.

Research on the biological effects of such radiation has been under way for more than a quarter of a century but has been vastly intensified since the possibility of constructing an atomic bomb was conceived and since the national effort was mobilized to produce such a weapon. Space will not permit a review of the voluminous literature which has appeared since 1940 on the metabolism of various stable and radioactive isotopes including those of the rarer elements not normally entering into metabolic processes nor on the effects of radiation from such isotopes on cells, tissues, organ systems, and whole animals. An example of this intensive research may be found in the 824-page volume 22-I of the Plutonium Project Record, edited by William Bloom (1948) which was reviewed by F. N. Low in the Quarterly Review of Biology (1949). Low says in his review:

> Although much information of great value has been obtained, it is frankly stated that the fundamentals of damage by irradiation are still not understood. No information on the basic mechanism is available. The patterns according to which some tissues and cell types are affected and others are spared are well recognized but the reasons for this selectivity are unknown. It is not known why irradiated animals die.

This is perhaps an extreme view which emphasizes the lack of precise knowledge of the causes of radiation damage. A somewhat more optimistic statement regarding the status of knowledge is presented by Austin M. Brues of the Argonne Laboratory and the Institute of Radiobiology and Biophysics at the University of Chicago. In a semi-popular article, Dr. Brues (1948) states:

> The various forms of ionizing radiation work through a chain of events common to all. Although they are physical agents, they act in the body very much as a chemical agent might. . . .
>
> The chemical effect of radiations is due to their capacity to break up certain chemical configurations. The case of damage done to water is fairly well understood and since the body is mostly water, this is probably the most important case. Ions are formed from water molecules, of a type not usually occurring in water, which last for an almost unmeasurable length of time, but do their damage during this period. Hydrogen peroxide is one of the combinations formed. But certain essential enzymes can be paralyzed, certain sensitive cells are destroyed, and changes in chromosomes and other visible parts of the living cell may later result in inherited changes, and perhaps may account for cancer. This all sounds very serious, but perhaps we can take the bloom off it by pointing out that no radiation effect exists which cannot be duplicated by the action of some known drug or chemical. Chemical agents are known, in fact (and some of them may be encountered in ordinary life), which will cause genetic mutations. Cancer can be made more likely to occur by radiation exposure, but exposure to sunlight will also increase one's chances of skin cancer. Total body radiation exposure will shorten the life span, but tobacco smoking is another efficient way to accomplish this result.

Aside from the extensive studies on genetics using radiation to produce gene mutation and chromosome changes in the fruit-fly, in corn and other higher plants and molds, protozoa and bacteria, nearly all the experiments concerned with the physiology and pathology of irradiation have been conducted on mammals—the usual laboratory animals such as mice, rats, guinea pigs, rabbits, and dogs. Among these animals there is considerable difference in the amount of radiation which constitutes a lethal dose. Moreover, since the object of many of these studies, based on the urgencies of war, was the determination of human tolerance limits, the dosages employed were generally high—in the hundreds, thousands, and ten-thousands of Roentgen units.

Dr. Shields Warren (1949) of the Atomic Energy Commission summarized in a general way the great differences in the resistance of organisms to radiation by stating the LD-50, the dose sufficient to kill 50 percent of the population receiving it, as determined by various investigations. In general, bacteria are resistant, the killing dose exceeding 200,000 r. Viruses withstand hundreds of thousands of r. In *Paramecium,* the LD-50 is about 300,000 r. In the pupal stage of some insects, the LD-50 is about 150,000 r. In the rat it is between 825 and 900 r. The guinea pig is one of the most sensitive animals; the LD-50 is about 250 r. In humans the lethal dose for half of those exposed is about 400 r. Plants, in general, are far more resistant than are animals.

Few studies have been carried out on the radiation pathology of cold-blooded animals and still fewer at low levels of radiation. There is very little in the literature, therefore, to guide us in selecting specific radiation effects in studying the animals of a stream receiving radioactive wastes.

Bonham, et al. (1947) made a brief study of the effects of x-rays on several marine micro-plankton organisms but high exposures of from 1,000 to 50,000 r were used. As found by others, Protista are quite resistant, the LD-50 for a mastagophoran being about 50,000 r and of the same order for *Nitzschia* and *Chlorella.*

Bonham (1949) also studied the effect of x-rays on the fresh-water snail, *Radix japonica,* at doses from 500 to 80,000 r. Immediate death of some adult snails was caused by exposure of 1,000 r and embryonic growth in egg masses so exposed was markedly retarded but crawling activity of the young was not reduced at that dose.

The only extensive study of the effects of penetrating radiation on fish reported in the literature has been carried out at the University of Washington. Welander (1945) reported the gross anatomical and the histopathological effects of x-rays on the growth and development of the embryos and larvae of Chinook salmon. Eyed eggs were exposed to graduated doses of from 250 r to 10,000 r and observed for 18 weeks. Exposure to 1,000 r retarded the development of skin pigment, vascular system, fin rays, interrenal bodies, glomeruli of the kidneys, and probably other organs. After 125 days the length was 19 percent less, and the weight 40 percent less, than in controls. About 13 percent of the young fish died after 37 to 51 days and 24 percent 79 to 100 days after exposure, probably from injury to the hemopoietic tissue and to the gastro-intestinal tract. The most sensitive measure of radiation damage was the number of pycnotic cells (showing damage to the chromosomal material of the nucleus) in the hemopoietic tissue of the kidney, injury being detected at exposures as small as 250 r. In all the criteria of damage observed, the effects were proportional to the exposure.

Welander, et al. (1949) also studied the effects of x-rays on adult rainbow trout at exposures of from 50 r to 2,500 r. Exposures to 1,500 r killed 56 percent in 13 weeks and 87 percent in 64 weeks. Injuries symptomatic of radiation seen in fish exposed to 500 r or more, such as hemorrhage, necrosis, growth of fungus and intestinal damage, were generally proportional to the exposure. Growth was retarded in all fish receiving 750 r or more.

As was noted, none of these studies is concerned with the biological effects of low-level radiation. It is in the voluminous literature on genetics that evidence of damage from low-level radiation is found. Since the discovery of the mutagenic effects of x-rays by Müller in 1927, it has been well established that penetrating radiation produces chromosomal derangements and gene mutations which are inherited, that the mutation rate is proportional to the exposure, and that there is no threshold dose. (See Lea, 1947, for a full review of this subject.) The most recent contribution I have seen is a note in *Science* of June 17, 1949. Uphoff and Stern (1949), repeating studies checking the proportionality between the r-dose and the mutation frequency, confirm previous findings on this proportionality and conclude:

> Viewing all experiments together it appears that irradiation at low dosages, administered at low intensity, induces mutations in *Drosophila* sperm.

I have no intention of belaboring the thought that aquatic populations exposed to radioactive wastes will undergo early and obvious genetic changes because the mutation rate may be increased 0.002 percent per r of radiation exposure. No judgment is offered on whether an accelerated rate of mutation is in itself good or bad from the evolutionary point of view. In the hands of the plant and animal breeder it has been turned to great human advantage. But the vast majority of mutations are recessive and the majority of these are detrimentals or lethals. The accumulation of a recessive mutation in the germ plasm of a population to the stage in which all individuals are homozygous for that gene is speeded when the breeding population is restricted in numbers. Stream populations are probably more restricted than are marine or most terrestrial populations and hence mutational changes may be more promptly fixed in the germ plasm. As recessive lethal genes increase in number, the breeding potential of the population falls. Hence, where the rate of breeding is a dominant factor in controlling the size of a population, the increased rate of mutation and the accumulation of recessive detrimental or lethal genes induced by the continuous action of low-level radiation may cause a persistent decline in a stock of fish.

In summary, injury to aquatic organisms from radioactive wastes may be caused by direct tissue damage, by the derangement of physiological processes, or by genetic changes induced by continued exposure to external or internal radiation. Such injury will impair the health or will result in early or later death of the exposed organisms or of their progeny.

A number of speculative predictions or hypotheses may be advanced regarding the practical effects of radioactive wastes in streams. It is unlikely that the lower forms of life such as bacteria, protozoa, algae, worms, mollusks and the like or higher plants will show any immediate or obvious effects. Damage to fish probably will be evidenced chiefly by depressed reproduction, retarded growth rates, increased "natural" mortality, and reduced life-span. Whatever the mechanism of damage, exposed populations may be expected to dwindle in size over a period of years and, if the susceptibility or the exposure of the different species varies because of habitat preferences or feeding habits, the species-composition of the population will change also. The degree and rapidity of all these changes will depend on the amount of radiation absorbed.

An Ecological Study Including the Effects of Radiation

Early in 1949, it was proposed to the Atomic Energy Commission that these hypotheses should be tested, that the effects of low-level irradiation on fish and other aquatic organisms should be studied more directly and intensively and that an objective appraisal of the success of current methods of radioactive waste disposal, as reflected by conditions of life in streams, should be made. After a series of discussions with officials of the Atomic Energy Commission in Washington and at Oak Ridge and with staff members of the Oak Ridge National Laboratory and the Tennessee Valley Authority, the concept of the investigation was expanded to include a wide range of important factors concerned in the ecology of the watershed.

The White Oak Creek drainage, already mentioned, was selected as the area of study. It has many advantages. While, doubtless, many of the problems which deserve critical study can be investigated only by direct experiment where the various factors can be controlled and varied at will, White Oak Creek, which already has received considerable quantities of radioactive waste and is receiving additional contributions daily, presents a graduated series of radiation hazards and possesses an apparently abundant fauna and flora typical of Eastern Tennessee.

A great deal of knowledge concerning the ecology of Tennessee waters, the bottom organisms, plant life, insect life, and fish populations in these streams has already been accumulated by biologists of the Tennessee Valley Authority. The kinds and amounts of radioactive materials in the waste effluents from the Oak Ridge plant, together with daily and weekly monitoring of radiation levels in the creek bottom and in waters flowing into the Clinch River, are recorded by the Atomic Energy Commission. Uncontaminated waters of the Tennessee River system are available nearby to serve as control areas for comparison. While aquatic populations will vary materially from season to season and from year to year in one stream and in the same year in different streams, conditions suspected of being aberrant in White Oak Creek nevertheless can be compared with long-time trends and with average conditions where no pollution is present.

The project will be conducted with the cooperation of specialists in nuclear physics and radiochemistry from the Oak Ridge National Laboratory and biologists from the Division of Health and Safety and an augmented staff from the Branch of the Fish and Game of the Forestry Relations Division, both of the Tennessee Valley Authority. It is expected also that cooperation from one or more universities will be accorded.

The broad outlines of the investigation include the physical assessment of the area and the limnology of the White Oak Creek drainage. Extensive study of radioactive contamination will be undertaken. This will include the source, quantity and character of contamination, the rate of addition and removal of activity by physical decay, ion exchange, dilution, sedimentation, and transport of bottom sediments. The contamination by sanitary wastes will also be examined.

Seasonal and long-time changes in the biota of the White Oak Creek drainage will be studied with special reference to the plankton, non-plankton algae, rooted vegetation, invertebrate bottom fauna, and vertebrate fauna. Special attention will be given to a study of the fish-population biology of the drainage and adjacent waters including species composition, migration, quantitative estimates of the seasonal and annual changes in population numbers, and changes in the size- and age-composition of key species. The growth history of certain species, recorded on the fish's scales, will be studied in relation to changing ecological factors including radiation and habitat preference, food supply, feeding habits, and predation. Careful observations on spawning success and the survival of annual broods will be made.

Another aspect of the study will be the radiobiology of White Oak Creek. This will include the distribution of radioactivity in the water and bottom sediments and the assay of selected species in each of the life groups to determine selective absorption and the rate of concentration and the localization of radioactivity. Observations on radiation damage to fish will include histopathology, growth history and life span, the more obvious genetic abnormalities, mortality, and rate of reproduction under different levels of radiation exposure.

These observations will permit a considerable series of comparisons and correlations to discover significant causes of conditions observed both in White Oak Creek and in similar ecological situations unaffected by Oak Ridge wastes. If continued for a sufficient period of years, long-time trends will be discovered. The study should yield theoretical and practical information in the fields of ecology, limnology, and fishery biology and in the fields of radiobiology and "sanitation" as applied to the safe disposal of radioactive wastes.

Radiation as such is not new, as was stated in the beginning of this paper; but radioactive waste disposal, on the scale which we are encountering for the first time and which will grow in importance through the years, is an entirely new element never before encountered in the ecology of aquatic organisms. This new element must be given due consideration by ecologists and biologists in future investigations.

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APPENDIX

Background Information about Radioactivity, Units for Measuring Radiation, and Permissible Limits of Exposure[1]

There are different kinds of atoms called isotopes in nearly all of the chemical elements (hydrogen, oxygen, carbon, iron, copper, etc.). The atoms of any chemical element are alike in their chemical behavior — the way they combine to make all material things. Most elements, however, have atoms that are not alike in their nuclear properties.

For example, every copper atom has 29 electrons whirling about its nucleus, and it is this number (the atomic number) that identifies copper chemically. The 29 electrons make copper behave the way it does chemically.

But the nuclei of some atoms of copper contain a total of 63 particles (29 protons and 34 neutrons), while the nuclei of other atoms of copper contain 65 particles (29 protons and 36 neutrons). Since these two kinds of copper atoms have different numbers of neutrons in their nuclei, they have different atomic weights. They are the two natural or "stable" isotopes of the element copper.

Copper atoms can be made, in nuclear reactors and in cyclotrons, which have nuclei containing some other number of neutrons than 34 or 36. These artificial nuclei are unstable. Any one of them sooner or later converts itself into a stable nucleus by giving off particles and energy rays. These artificial "unstable" copper atoms are called the radioisotopes of copper. The radiations from the radioisotopes of the various elements are all different, but they all are able to penetrate solid matter to a greater or lesser degree, and they all have definite detrimental effects on living tissues.

Scientists have various ways of measuring radiation depending upon the uses to which the measurement is put. One common unit of radiation is the curie (c) which tells the number of radioactive atoms that disintegrate in an interval of time. One curie is arbitrarily taken as 37 billion disintegrations per second; a millicurie is one-thousandth of this amount, 37 million disintegrations per second; a microcurie is one-millionth, 37 thousand disintegrations per second. The curie is a convenient measurement for monitoring purposes since it indicates the amount of radioactive materials present.

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[1] From Seminar on the disposal of radioactive wastes. Atomic Energy Commission, Press Supplement No. 154, January 30, 1949.

Physical scientists, biologists and physicians require a unit of radiation that gives some indication of its effect on other materials. A common effect of radiation upon other materials, such as air or lead or living tissue, is its ionization effect in which molecules of the medium become electrified by impact or passage of the radiation. In living tissue, ionization is related to the death of cells. On creating ions in the medium (living tissues, etc.) the radiation loses energy. The energy is absorbed by the medium. The Roentgen (r) is the unit of energy absorbed by air. One Roentgen equals 83.8 ergs per gram of dry air. It is used specifically to measure x-rays and gamma radiation.

The Roentgen Equivalent Physical (rep) applies to particle radiation — alpha, beta, neutron, deuteron, proton and the like — in living tissue. It is also a measure of the amount of energy absorbed by tissue. One rep equals 83.8 ergs per gram of tissue. In general, one r does not equal one rep, since energy loss for one r of gamma radiation in tissue usually is greater than 83.8 ergs per gram.

Our knowledge of radiation effects is based mostly on medical and biological experience with the x-ray and with gamma radiation from radium. We know, for example, that if a group of people were given a single dose of gamma radiation of 450 r about half of the group would die. However, most individuals could take 450 r if it were not given in a single dose but in a series of small doses over a period of several months. A diagnostic chest x-ray is equivalent to about 10 r. Experience reveals that most individuals can withstand a daily dose of 1 r indefinitely without apparent injury. In setting a permissible limit, doctors incorporate a factor of safety of about 10; hence, 0.1 r per day is the standard permissible limit for continuous exposure. This applies to persons working in atomic energy installations and physicians and nurses working with x-ray.

Each of the 600 or 800 radioisotopes of the 96 known elements has a different scheme of radioactivity — that is, the radiation consists of varying types of particles and rays having various energies. Thus, the effect upon tissue of the radiation from each isotope is different.

Many of these have been investigated, including radioiodine, radiosodium and radiophosphorus which are commonly used in medical therapy and research. When information is available special permissible limits may be established. Often, however, the health physicist has inadequate information upon which to base special permissible limits or he may be dealing with a mixture of radioisotopes. In these cases he sticks to the most conservative permissible levels — levels which he is sure will result in no harmful effects.

Conservative permissible limits for radiation in drinking water are of the order of 10^{-5} microcuries per cubic centimeter, and for air which is breathed about 10^{-8} microcuries per cubic centimeter. At atomic energy installations an additional factor of safety of 10 or 100 is added in establishing permissible limits for liquid and gaseous wastes which are discharged into streams or the atmosphere.

Part 11

Business Sessions

AMERICAN FISHERIES SOCIETY

SEVENTY-NINTH ANNUAL MEETING

The seventy-ninth annual meeting of the Society was opened in the Royal Alexandra Hotel, Winnipeg, Manitoba, at 9:00 a.m., Wednesday, September 14, 1949. The agenda were as follows:

Wednesday, September 14

Morning and Afternoon: Joint field trip with the International Association of Game, Fish and Conservation Commissioners to the Delta Waterfowl Research Station or on the Red River to Lake Winnipeg, under the auspices of the Game and Fisheries Branch, Manitoba Department of Mines and Natural Resources.

Evening: Annual Banquet—Main Dining Room.

Thursday, September 15

Morning: Opening remarks of the President; appointment of sessional committees; reports of officers, standing committees, and special committees.

Afternoon: Presentation and discussion of papers.

Friday, September 16

Morning: Presentation and discussion of papers.

Afternoon: Presentation and discussion of papers; reports of sessional committees; election of officers and installation of the new President; concluding business.

OPENING REMARKS OF THE PRESIDENT

SETH GORDON

During the past year your officers have attempted to keep the members of the Society well informed as to what was going on. It costs money to send out letters; but on the other hand, unless the members of the Society are kept fully informed, we cannot hope to have all of them co-operate as they should.

A little later Dr. Ralph Hile will tell you something about the status of the TRANSACTIONS. As you know, inability to get the TRANSACTIONS printed and distributed more promptly has caused the Society a great deal of grief. I do not want to steal any of Dr. Hile's thunder, but his report will be very pleasing and encouraging to you.

I do not know how we can ever thank Ralph Hile and his co-workers enough for what they have done in these trying times to bring the TRANSACTIONS up to date. He and his associates have been doing yeoman service. Your President knows something about the long hours they have devoted to the task. Before we had such an editorial board, your humble servant tried to keep those TRANSACTIONS going. We spent many weary hours, just as Ralph Hile did, burning the midnight oil, sometimes breaking the Sabbath, in order to further the work of the Society. I want to express my sincere appreciation to the editor and his associates for the work they have done to bring the TRANSACTIONS up to date.

The new Western Division of the Society got off to a very good start. I attended the first annual meeting at Seattle in June. We had more people present at that meeting than we have right here now. Actually they had a most inspiring meeting. You will get a special report on it later. Apparently the one place to bring the work of our Society "close to home," as we say in our Pennsylvania Dutch, is the regional meeting. At the regional meeting the members seem to realize more fully that they each play an important part in the work of the organization. I believe the time will come very soon when we will need to set up more of these regional units.

The Committee on Revision of Constitution and By-laws has been labouring with a will and Dr. Deason will report the committee's conclusions later on. This committee either did such a good job that there was little criticism of the recommendations, or there was a shocking lack of interest on the part of the membership. I am confident it is not the latter. Dr. Deason and his associates deserve the Society's sincere appreciation.

The membership of the Society has increased very nicely during the past year. The membership committee, headed by Vice-President M. C.

James, was on the job. It is comforting to know that we have made substantial gains. If we can increase our membership to at least 2,000 by the end of the coming year, we can then do many of the things which are not possible at the present moment. And we may be able, when we attain that goal, to reduce the membership fees for individuals.

There has been a suggestion that the Society should have a lapel emblem for the member. We had a special committee look into it, consisting of H. H. MacKay and John Van Oosten. Those gentlemen believe that the Society is not ready for an emblem of that kind, largely because we do not meet frequently enough.

The financial statement will be presented in detail by the Secretary-Treasurer; but, as I stand before you today, I feel much relieved about what I feared a year ago might be a bad situation. We are in much better shape financially than anticipated. We negotiated better printing contracts, and George Sprecher has been doing a good job of collecting dues.

During the coming year, many more of you members must help to increase the membership, also to restore the fund that was established some years ago to take care of emergencies.

The program prepared by the committee headed by Vice-President A. S. Hazzard speaks for itself. We do have a problem before us, for the discussion of which we ought to apologize to our members in the Dominion. That is the question which has arisen with reference to recommended improvements in the administrative set-up in the United States concerning our natural resources. We shall have a special report on that later.

There has been some question whether this Society could afford, or be willing, or have courage to take action in that matter, or whether we should by-pass it. As far as your President is concerned, this Society ought to take positive action one way or the other, and thus relieve the incoming President of any embarrassment that might result if the Society fails to take action.

We have present at this convention, for the first time in a number of years, a goodly number of members of boards and commissions throughout the United States and Canada, particularly the commissioners who serve without pay, the policy-makers. They had an evening session here. Commissioner Brown of Missouri, who was the chairman of the meeting, requested me to convey to all of you the information that at the conclusion of that meeting the other night it was agreed by all present that each year the International Association shall plan for a period when they can have an evening session just like that—a round-table session where those who are responsible for determining policies, making regulations, and so on, may "talk shop" without the customary agenda of business.

Commissioner Brown requested me to announce that the next time such a meeting is held it will be open to anybody who wants to sit in and listen, and that nobody is going to be embarrassed by being asked to absent themselves from the room.

There may be enough commissioners here who might like to have a luncheon together, or who prefer to use the evening hour for a further discussion of their problems. If so, and members of such boards and commissions will make known their wishes, we will try to arrange it.

Some of you members may wonder why I should mention this matter here. Unless we can maintain the interest of these non-paid members of boards and commissions, we will fail in our duty. After all, they are the ones who should hear your discussions, and those of the International Association, so that they may be better informed.

APPOINTMENT OF SESSIONAL COMMITTEES

Time and Place

George W. Davis, Vermont, *Chairman*
George E. Butler, Manitoba
Clarence F. Pautzke, Washington
E. B. Speaker, Iowa
A. H. Wiebe, Tennessee

Auditing

Lloyd L. Smith, Jr., Minnesota, *Chairman*
Robert O. Beatty, Illinois
G. C. Armstrong, Ontario

Resolutions

C. R. Gutermuth, District of Columbia, *Chairman*
Richard Croker, California
Richard Miller, Alberta
Fred A. Thompson, New Mexico
A. L. Pritchard, Ontario

Nominations

Joe Hogan, Arkansas, *Chairman*
H. H. MacKay, Ontario
Vadim D. Vladykov, Quebec
K. H. Doan, Manitoba
Eugene W. Surber, West Virginia

Publicity

George E. Butler, Manitoba, *Chairman*
Gerald P. Cooper, Michigan
Hjalmer Swenson, Minnesota

REPORTS OF OFFICERS

REPORT OF THE SECRETARY-TREASURER

George E. Sprecher

The report of the Secretary-Treasurer is divided into two parts: first, my activities as secretary, and, later, a treasurer's report.

On November 17, 1948, the books of the Society were turned over to me. On December 1, 1948, a general letter was sent to all members of the Society which included a brief report of the Atlantic City meeting of the Society held on September 13, 14, and 15, 1948. The letter urged all members to make every possible effort to increase the membership of the Society.

Your Society was represented by its Secretary at a meeting held in Washington, D. C., on November 30, 1948, where representatives of various national conservation organizations came to discuss proposed conservation legislation. This meeting was called by Mr. Albert M. Day, Director of the U. S. Fish and Wildlife Service, and was very effective in correlating the efforts of the national conservation organizations to promote sound conservation legislation.

On March 8, 1949, a meeting of the Executive Committee of the Society was held in Washington, D. C. Several important administrative steps were taken at this meeting, including the following: (1) the Secretary-Treasurer was authorized to sell all securities other than government bonds and to place all future investments in U. S. government securities; (2) the President and the Secretary were authorized to approve applications for new members, such action to be binding on the Society; (3) the Secretary was authorized to provide each member with a membership card; (4) the Secretary and the Editor were authorized to obtain fire insurance on all library property of the Society; (5) the written report of the Librarian was approved; and (6) it was agreed to support several important bills which were then before Congress.

A general letter sent to all members of the Society on March 1, 1949, advised the membership of the improved financial condition of the Society, and of progress being made in publishing the Transactions. You are all aware of the fact that Volume 76 was published and distributed during the past fiscal year. Volume 77 is now being distributed. We are informed that Volumes 78 and 79 will be published during the next fiscal year, and we will then be up to date on all publications.

On July 1, 1949, a preliminary announcement of this meeting was sent to all members, and on August 15, 1949, a final call to the meeting was issued. The final call included a copy of the new proposed constitution and by-laws. All members should now be well informed as to the progress made by your Society.

This report would be very incomplete if I did not recognize the tremendous amount of co-operation which was provided me by various officers and members of the Society. The President, Editor, and Librarian have been extremely helpful in aiding me in my work, and have also been the principal forces in overcoming the difficulties which beset the Society at the beginning of the year.

MEMBERSHIP REPORT

Class of Membership	*1948*	*1949*
Active	592	895
Club	16	17
Life	42	45
Library	39	48
State	32	33

FINANCIAL REPORT

Funds of the Society were turned over to me as Treasurer on November 17, 1948. These funds consisted of a general fund of $2,763.89 in cash, and a permanent fund of $7,641.66 in cash and of securities valued at $2,015, a total value of $12,420.55 in both funds.

Immediately after the 1948 meeting of the Society, the Executive Committee authorized the Secretary-Treasurer to use permanent fund monies to pay the bills of the Society whenever the general fund was exhausted. Almost immediately the fund was depleted by large disbursements, such as a $2,500 final payment for printing Volume 75.

On December 14, 1948, an appeal was sent to all members whose dues were in arrears. The results were highly gratifying. On June 30, 1949, after paying out $9,653.37, of which $8,487.07 was for printing of TRANSACTIONS, the net deficit to the general fund was only $1,846.64. In other words, the members of this Society paid in dues totalling more than $3,300 during this period. In addition, the Librarian sold TRANSACTIONS and other publications in the amount of $1,631.97. The permanent fund was increased considerably by dues from new life members and by income from investments. The balance on hand in this fund on June 30, 1949, was $8,138.16, which, added to the securities held, amounts to a total of $10,225.66.

Since June 30, 1949, the value of the general fund has changed to a balance of $1,338.61. The permanent fund now consists of $8,122.88 in cash and $2,236.25 in securities.

The financial future of the Society appears much brighter than it did a year ago. A new contract covering the publishing of the TRANSACTIONS will reduce the cost of each volume by approximately $2,000. The in crease in dues will also aid in placing the Society on a sound financial basis. The permanent fund, of course, will have to be used to a considerable extent to take care of current obligations. The foresight of earlier officers in establishing this fund is now recognized. Also, the efforts of so many members to increase the membership of the Society during the past year deserves the highest praise as such efforts have now placed the Society on a sound financial footing.

A financial report as of June 30, 1949, follows:

July 1, 1948 — June 30, 1949

GENERAL FUND

Balance on hand, July 1, 1948			$2,856.14
Receipts:			
Annual Dues			
Individuals			
For the year	1942-43	$ 3.00	
	1943-44	3.00	
	1944-45	6.00	
	1945-46	12.00	
	1946-47	81.00	
	1947-48	1,086.00	
	1948-49	2,002.50	
	1949-50	215.50	
	1950-51	9.00	3,418.00
State Memberships			
For the year	1945-46	20.00	
	1946-47	60.00	
	1947-48	260.00	
	1948-49	654.00	994.00
Library Memberships			
For the year	1944-45	12.00	
	1945-46	48.00	
	1946-47	66.00	
	1947-48	70.00	
	1948-49	84.00	
	1949-50	7.00	287.00
Club Memberships			
For the year	1947-48	60.00	
	1948-49	70.00	
	1949-50	5.00	135.00
Sale of TRANSACTIONS and Special Publications			$1,887.41
Sale of Index			34.00
Sale of Reprints			16.85
Collection of Checks and Postal Notes			27.43
Credit on Rental of Safety Deposit Box			4.86
Stamps received from W. C. Beckman			1.02
Balance of account from Riverside Trust Co.			5.35
Total Receipts			$6,810.92
Total Receipts plus July 1, 1948, Balance			9,667.06

Disbursements:

Printing of Transactions		$8,487.08
Other printing		1,309.59
Postage		222.70
Editing		290.30
Stationary and supplies		102.80
Reporting Services (E. C. Young)		275.00
Express and Freight		114.38
Refund on Transactions		24.00
Redemption of Bad checks		40.00
Clerical Services		123.40
Salaries:		
R. P. Hunter	$100.00	
K. M. Kane	49.65	
V. F. Smith	30.00	179.65
Withholding tax on salary of K. M. Kane		34.02
Travel expense:		
K. M. Kane	$ 55.00	
R. Hile	107.40	
G. E. Sprecher	44.60	207.00
Fidelity Bond		18.75
Fire insurance		43.38
Miscellaneous (rentals and collection fees)		41.65
Total disbursements		$11,513.70
Total disbursements, general fund		11,513.70
Total receipts plus July 1, 1948 balance General fund		9,667.06
Deficit, general fund June 30, 1949		($1,846.64)

Permanent Fund

Balance on hand, July 1, 1948		$6,711.22
Receipts		
Individual Life Memberships	$522.00	
Dividends on Commonwealth and Southern preferred stock	60.00	
Mortgage certificates		
Income distribution	16.40	
Principal distribution	145.00	
Interest on savings account	33.54	
Sale of government savings bond	650.00	1,426.94
Balance on hand, June 30, 1949		$8,138.16
Balance, June 30, 1949, general fund		(1,846.64)
Balance, June 30, 1949, permanent fund		8,138.16
Balance, both funds		$6,291.52

Securities Held, June 30, 1949

(1)	N. Y. Title and Mortgage Company, Series F-1 Certificate No. 10811	Paid in full
(2)	Title Guarantee and Trust Company Certificate No. 103553	$ 40.00

(3)	Title Guarantee and Trust Company Certificate No. B-71070	40.00
(4)	Commonwealth and Southern Preferred Stock 10 shares at 102.75	1,027.50
(5)*	U. S. Government Savings Bond No. M5 92089D	980.00
	Total	$2,087.50

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*This bond will become due August 1, 1949, and will be turned in at that time.

Since July 1, 1949, the income of the Society has been $3,370.11, which wiped out the deficit in the general fund and put it where it shows a balance.

REPORT OF THE LIBRARIAN

William C. Beckman

The back volumes of the Transactions were received from the former Librarian, Mr. Kenneth Cobb, on November 21, 1948. Shelves for their reception were constructed in the building housing the Institute for Fisheries Research, Michigan Department of Conservation, and the volumes were unpacked and inventoried on December 1, 1948. At that time 2,118 volumes, 568 cloth-bound indexes, and 186 paper-bound indexes were on hand.

Between December 1, 1948, and August 1, 1949, 746 volumes were distributed. During this same period the volumes for 1945 and 1946 were received. An inventory was taken on August 1, 1949, at which time 2,299 volumes were on hand. The cloth-bound index numbered 544, and the paper-bound index 174 copies.

In addition to the Transactions and Indexes, 3,371 copies of Special Publication Number 1 entitled *A list of common and scientific names of the better known fishes of the United States and Canada* were on hand when I became Librarian. Reviews were requested of editors of publications, and two items were published in the *Outdoor News Letter* of the Wildlife Management Institute. Sales of the list increased greatly after each item appeared. As of August 1, 1949, 1,436 copies were distributed.

A number of issues of the Transactions are now out of print. If any of the members have duplicate copies of the volumes from 1933 to 1941, inclusive, I would like to have you contact me. A number of libraries are interested in filling in their sets.

I also urge that every member of the Society secure for himself and his organizational library a copy of the Index. This Index covers the period from 1872 to 1928.

I also suggest that the members who do not have all the available volumes might do well to invest a few dollars and get them. In reading through some of the older volumes one can find many so-called "modern" ideas. Let me quote just one sentence from a "born-thirty-years-too-soon" paper:

> "These charts indicate that, unless the only limiting factor in a lake, pond or stream is insufficient breeding areas, or other factor wholly effective before the stage at which plantings are made, it is a total loss to introduce young fish of a species already established without making suitable adjustments providing for them, since they will be consumed together with the percentage already being eliminated by other factors."

That was in a paper published in 1922.

The prices on the volumes are $1 for all volumes up to 1930, $3 for 1930 to 1945 volumes, and $4 for the 1946 volume. I will be ready for orders as soon as the Library is forwarded to me at the Colorado A & M College, Fort Collins, Colorado, around the first of October.

REPORT OF DIVISION OF FISH CULTURE

E. B. Speaker

Fish culture in the United States is said to have had its origin with the efforts of Seth Greene, who established the first *bona fide* fish hatchery at Munford, New York, in 1864. The art has enjoyed a continuous existence since that time, and has been expanded as a tool of fish management to nearly every state and province.

Since the turn of the eighteenth century, and perhaps earlier, the citizenry of North America has been gravely concerned about the depletion of certain species of fishes. With the advent of the fish hatchery it was felt that "native" and new species might be increased to perpetuate angling. For over 75 years fish culture has flourished, and brilliant minds have perfected techniques which have enabled state, provincial and federal agencies to produce fish in astronomical numbers.

Until a relatively short time ago, it was felt that propagation of large numbers of fish was the only means of coping with the ever-increasing angling pressure exerted on the lakes and streams. Hatcheries were geared to produce maximum numbers of virtually every known species. Since little was known of habitat requirements or maximum carrying capacities, stocking was often more detrimental than beneficial.

Some twenty years ago, a considerable number of technically trained men were assigned to study the fresh-water and pelagic fishes in a nation-wide effort to base fish management upon scientific findings. Currently, administrators, managers, culturists, and scientists are working harmoniously together in an effort to utilize the product of the hatcheries to good advantage as a management tool, and not as a panacea to cure all ills.

More and more hatchery products are used to stock newly created waters, balance existing fish populations, re-stock areas which have become depleted by pollution or winter-kill, supply initial stocks to farm ponds, furnish adult stocks for small lakes in metropolitan areas, furnish a part or all of the trout fishing in heavily fished waters, and serve a useful purpose in scientific studies, rather than to attempt to furnish all fishing, *per se*.

Mr. George Eicher presented a comprehensive paper at the 1946 annual meeting of this Society, pointing out current trends in state fishery programs. He found most states were increasing their program to rear more creel-sized trout and had a tendency, or at least a desire, to curtail production of some of the warm-water species. There is little change in the trend at this time.

A comprehensive report was published in the January, 1949, issue of the *Progressive Fish-Culturist* by Tunison, Mullin and Meehean, bringing us up to date on the present status of fish culture in the United States. From this report we learn there are 522 fish-producing units operated by the states and 99 by the federal government. The combined production of these hatcheries totals nearly 3 billion fishes. This is indeed a sharp reduction in the 10 billion reported by Aldrich in the Society's 1937 annual report. During the fiscal year of 1947-48, over 67 million dollars was expended on the operation of these hatcheries. Personnel in the 38 states reporting and in the Fish and Wildlife Service totalled 133 men in administrative positions, 965 fish culturists, and 755 other employees. All told, 324 research men were employed by these agencies.

A questionnaire just received by the writer from over forty states and five Canadian provinces reveals some interesting and pertinent facts. Although there has been a general reduction in the over-all fish production in the past 10 years, 30 of the 41 states reporting, and all 5 provinces, indicate they are expanding certain of their fish cultural programs. Nine of the states reported activities more or less static, and two were curtailing the work.

Twenty-seven administrators indicated they would increase the propagation of cold-water fishes if funds were available, and seven reported their hatchery needs were adequate. Twenty-two states would increase their warm-water fish production if funds would permit, and about an equal number felt their facilities were ample at this time.

Forty new hatcheries were added by the states last year, six were enlarged, and nine were abandoned. A total of 39 units, mostly rearing ponds, was added by the Canadians, and one unit was abandoned.

Expansion in the various hatchery programs last year was primarily in trout, salmon, large- and smallmouth black bass, yellow pike-perch, muskellunge, pike and grayling. Curtailment was largely with the warm-water fishes including crappie, bullhead, yellow perch, sunfishes, and commercial species.

Creel-sized trout propagation is still rapidly increasing. In 1949, a total of over 27 million creel-sized trout was stocked in the United States. This is an increase of about 50 percent over the 18 million reported by Eicher in 1946. There is a definite tendency in the states to stock larger numbers of catchable-sized fish, and in some areas this practice has resolved itself into a virtual put-and-take proposition.

In the warm-water fishes, expansion of programs is largely confined to large- and smallmouth black bass, yellow pike-perch, pike, bluegill, channel catfish, and muskellunge, in that order.

A total of 26 states participate in a farm pond or small private lake program. During the past two decades literally thousands of miniature lakes, ranging in size from a fraction of an acre to several acres, have been constructed for agricultural purposes. Many of these ponds are located in lake-less areas, and contribute materially to the local fishing. Original stocks are supplied by state and federal hatcheries, and usually consist of largemouth black bass and bluegills. Undoubtedly this program is responsible, at least to a degree, for the increased production of these species.

An attempt was made by eight states reporting to introduce new hatchery-reared fish not native to the waters. Silver salmon were successfully introduced into New York, several species were brought into Nebraska, Colorado, New Mexico, Arizona, and Arkansas, and the white bass plantings in Florida failed.

It was encouraging to learn most of the states now base their stocking programs, at least in part, upon investigation of the individual waters rather than solely upon the request of individuals or local organizations.

Most agencies use the forage or bait minnows produced as a by-product of the hatchery for fish food, but only 15 states are making a special effort to rear them for stocking or commercial purposes. Because of the shortage of bait minnows in some sections of the country, considerable time is spent on researches which will furnish information on culture, care, and transportation to commercial dealers. This will, ultimately, effect a saving on the natural supply.

Fish hatcheries and rearing ponds are utilized, in part, for biological investigations in 28 states and provinces. These studies include disease and parasites; hatchery diets; growth-rate; aquatic plant control; rough fish; effects of insecticides and herbicides upon the fishes; bait and forage minnows; effects of fishing and outboard motors on fish life; and many other valuable projects.

Sixteen of the states now have a formal training program of some type for their fish culturists. Thirty states indicated they thought this would be highly desirable, and five were opposed to it.

In conclusion it might be said that although there has been a drastic reduction in the over-all fish production throughout the country in the past 10 years, there seems to be an increase in the tendency to rear larger numbers of fish to catchable size. This is particularly true of the cold-water fishes and some warm-water species stocked in metropolitan areas. Demands from the ever-increasing angling fraternity may be partially responsible for these programs, but it is believed administrators and investigators are sincere in their efforts to provide maximum recreation with available funds. There is a general tendency to curtail production of certain abundant species and gear hatchery outputs to actual needs, rather than to produce optimum numbers for indiscriminate and promiscuous stocking. Hatchery programs, like all other conservation measures, can be altered only as rapidly as the public is conditioned to receive them. Close co-operation between administrators, culturists, research and publicity men can do much to enlighten the public on these matters and bring about effective and well-balanced management programs.

REPORT OF DIVISION OF AQUATIC BIOLOGY AND PHYSICS

W. J. K. Harkness

Inasmuch as this meeting of the Society is being held in Canada, and as I am more directly in touch with the Canadian picture, I may be excused for placing on record present Canadian developments as illustrating and relating to the general situation in the field of aquatic biology.

There has been a gradual and presently accelerating tendency to relate the work in aquatic biology to fisheries problems, fisheries production, and fisheries management. The biological survey *per se,* and the isolated research effort, are giving way to integrated studies, both long term and short term, conducted with improved methods and equipment, and in many cases, fortunately, employing designed experiments so that observations and results may have mathematical as well as biological significance.

In Canada, as well as in the United States, many investigations are being carried out to determine and measure suitabilities of waters for specific species of fish during part or all of their life histories. In British Columbia, Larkin's work as related to trout; the very extensive program of the Fisheries Research Board on the Skeena River relating to spawning runs and conditions for species of the Pacific salmon; Rawson's work on the saline lakes of Saskatchewan; and the combined work of Miller, Rawson, Doan, and Kennedy on the Prairie provinces and northern lakes, relates both to fish production potential and the multitude of factors which may be of value in the control of the economically important parasite *Triaenophorus*.

The work of McCrimmon on the factors controlling distribution of salmon and other species of introduced and indigenous fish in Duffins Creek, Ontario, is of particular significance in relation to effective use of hatchery-reared fish. Similar work is in progress in Quebec and the Maritime provinces of Canada.

Increasing attention is being given to nutrient sources and content of the water: Rawson in Great Slave Lake; Fry, Southbay experiment; and Chandler and Langlois of Ohio for Lake Erie. These investigations are being correlated with land geology and land use and are perhaps basic to the current interest in water fertilization by chemical and/or biological fertilizer, in which field the work of Swingle of Alabama, is, of course, outstanding; and there is a special approach in the Michigan program of work. In Canada, Smith has been carrying on fertilization experiments since 1930; in the Maritimes, Taylor has been working on trout waters of Quebec; and at the Ontario Fisheries Research Laboratory in Algonquin Park, Langford reports in private communication that he is adding chemical fertilizers to lakes, and following the changes in the chemical nutrients as well as measuring the amounts of incoming chemicals from the watersheds. Analyses of phytoplankton, zooplankton, benthos, and forage fish populations and growth constitute important aspects of his experiment, for which special apparatus and methods have been designed.

The work of Hutchinson in the United States, and Hayes working with Smith in the Maritimes, using radio-active tracers to trace the food cycle, is a new and promising direct attack on the dynamics of production.

In concluding, I wish to draw attention to the excellent work of Pennak in Colorado; Chandler on the altogether different problem of Lake Erie; and the other fresh-water work being carried out, especially in Wisconsin, Minnesota and Michigan; and to the rapidly expanding work of the oceanographers on both the Atlantic and Pacific coasts aided in no small degree by the introduction of high-speed and refined sampling methods and apparatus.

To summarize the fields of recent interest and development we might say that they include studies of geology, land and land use as factors in aquatic production, leading to work on artificial fertilization of impounded and natural waters; the relation of industrial and domestic effluents to aquatic conditions and production; and the factual elucidation of theoretical aspects of the dynamics of aquatic production.

I wish to thank Doctors D. C. Chandler, D. S. Rawson, R. R. Langford, A. L. Pritchard, V. E. F. Solman, and Mr. D. Omand for their assistance in compilation of this review of work in progress.

REPORT OF THE DIVISION OF ANGLING

WILLIS KING

The last report from the Division of Angling, prepared by James A. Rodd for the 1941 TRANSACTIONS of the Society, is a classic example of angling prose and poetry. I hope only to present a few facts and ideas on the subject and to point out in small measure the recognition due the sport of angling by our Society. In fact, most professional fisheries men, including members of our Society, would be in other occupations if it were not for the public interest in fishing.

Fishing is generally recognized as the most democratic of sports, including among its participants persons of all races, sexes, religions,

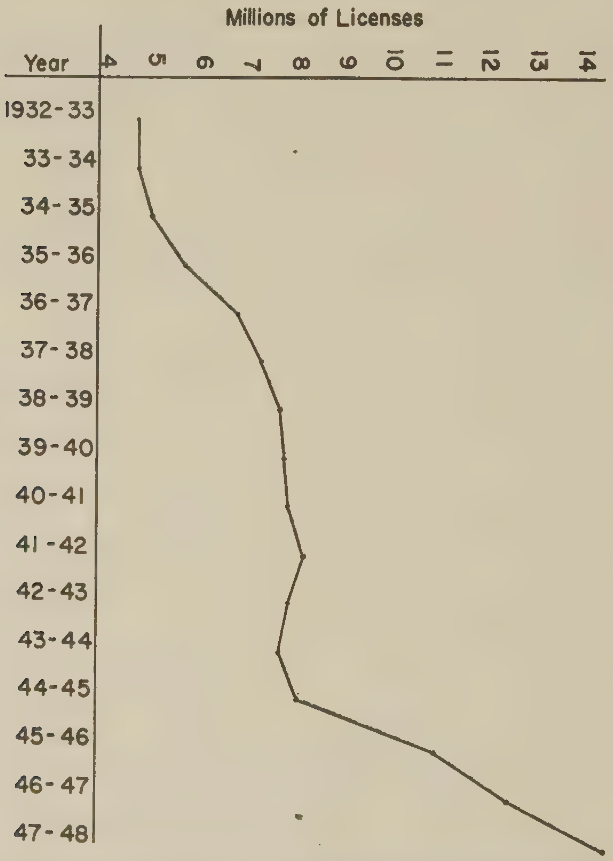

FIGURE 1.—*Fishing license sales for the United States as furnished by the States to the U. S. Fish and Wildlife Service, released by the Service.*

TABLE 1.—*Increase in fishing pressure in North Carolina, as shown by the number of licensed anglers.*[1]

Year	Number of Licenses	Year	Number of Licenses
1939	53,851	1944	62,272
1940	56,008	1945	73,779
1941	66,006	1946	103,622
1942	63,785	1947	154,113
1943	59,289	1948	208,660

[1] Data from biennial reports of the North Carolina Department of Conservation and Development and the first annual report of the Wildlife Resources Commission. Totals include the number of persons holding combination hunting and fishing licenses.

and all but the youngest in age. Even the fellow who prefers to be called an angler is a fisherman at heart. It then behooves us as professionals to take stock of our activities and to occasionally reestablish ourselves on a footing which recognizes our responsibility to every man who fishes.

The growth of interest in fishing is reflected in the sale of licenses throughout the United States. Data furnished by the United States Fish and Wildlife Service are shown graphically in Figure 1. Beginning in the fiscal year 1932-33, 4,858,058 license holders were reported. This figure climbed steadily to a peak of 8,423,218 in 1941-42. The war years brought a decline to 7,830,477 in 1943-44, but since that year the figure has climbed steadily. The last year for which figures are available, 1947-48, shows a record high of 14,582,739 licensed anglers in the United States. Leaving fact and turning to speculation, it seems safe to say that not over one-half of the persons who fish at least once a year buy a fishing license. Many of these persons are exempt by law. This gives a total of over 29,000,000 persons seeking recreation from the nation's streams, ponds, and lakes. This segment represents roughly one-fifth of our total population. Fishing cannot be regarded lightly either as an avenue of recreation or as an economic resource.

It is interesting to follow this trend in the southeast, where I have observed it during the past ten years. North Carolina has followed the same pattern as that shown in the summary for all states. Fishing license sales are now three times the pre-war figure of 1940 (Table 1). There is small wonder that, in the areas having the greatest numbers of people and the fewest fishable waters, there is some complaint of crowding and unhappiness over the results of the average fishing day.

To reduce the picture to a still smaller area, Chamberlain and Huber point out in the *Progressive Fish-Culturist* for October, 1947, the growth of public interest in trout fishing in the Pisgah Ranger District alone of the Pisgah National Forest. In the 10 years from 1937 to 1946, the number of fisherman days jumped from 1,091 to 8,202. Wildlife Resources Commission records show 10,267 fisherman days for the same streams in 1948 (Table 2). This is a ten-fold increase.

TABLE 2.—*Summary of 12 years of trout fishing on the Pisgah Ranger District in North Carolina.*

Year[1]	Fisherman Days	Total catch	Average catch
1937	1,091	6,322	5.8
1938	1,112	5,527	5.0
1939	1,605	7,667	4.8
1940	2,829	14,310	5.1
1941	3,563	18,373	5.1
1942	3,824	18,440	4.8
1943	4,471	18,231	4.1
1944	4,450	15,520	3.5
1945	5,097	23,407	4.6
1946	8,202	35,038	4.3
1947	9,257	36,090	3.9
1948	10,267	37,029	3.6

[1] First 10 years' data from Chamberlain and Huber, 1947; 1948 data from Wildlife Resources Commission files.

In unpublished data, Eschmeyer and Miller of the Tennessee Valley Authority state: "On the basis of data collected over a three-year period, all TVA tail-waters combined now support an estimated three-fourths million fishing trips a year with a catch of almost four million pounds." In the fiscal year 1946-47 a total (estimated in part) of 393,000 fishing trips were taken in the tail-waters of nine reservoirs. In 1947-48 the figure was 456,581, and in 1948-49 the number reached 657,054. This is an increase of 67 percent during the period.

This greatly increased public use places a growing burden on our hatcheries, law enforcement personnel, and fish managers. Can we meet the task ahead?

One aspect of the problem which should not be overlooked is the economic side. It is not purely a matter of more hatcheries, better equipment, or more personnel. Increased revenues are helping greatly, and may enable the production of sufficient warm-water fish to stock new ponds and lakes, and enable some corrective stocking on older waters. It is in the field of trout management that the critical point is approaching. The price of the trout fishing license does not ordinarily pay for one creel limit of trout. Who is to pay for any others that are taken? Anglers are not accustomed to buying a fishing license as they would a meal ticket, and desirable as this plan might be, the difficulties of enforcement render it hardly feasible. The warm-water fisherman has been carrying the load for the trout fisherman for a long time, and is beginning to tire of this burden. Several states are looking to a special trout stamp or license, with the proceeds to be earmarked for trout culture. This plan holds promise of being more widely adopted in the next few years. A second method of making the trout fisherman pay for his sport is by concentrating effort on state and federally owned management areas. Here daily permits are sold, as on the Pisgah, and the revenue used to further the program.

The fish-culturists are busy working out ways and means of reducing fish mortality, cutting the cost of producing catchable-sized trout and rearing more fish in available space. The idea of more fishing for fun and less for meat must be sold to the public. This is a matter of education. For practical reasons the angler's interest must be directed to less enticing species of fish, just as our appetites were directed to less expensive cuts of meat during the war years. A lot of fun and food are not being used in the southeast in the form of catfish, pickerel, carp, buffalo, suckers, and a host of other varieties of fish.

It would be unfair not to mention the possibility of improving our existing streams and lakes so they will support a larger number of anglers; although we must admit that no amount of improvement of existing waters, especially the trout streams, is going to provide the angling territory needed. It is not possible to create new trout waters in many parts of the country, although new water areas, both large and small, are increasing greatly the habitat for warm-water fish.

All of these things: improvement of existing aquatic environments; creation of new ones; more fish to stock vacant waters or correct unbalanced populations; more attention given to fish other than trout and the more costly species; more money both from license sales and federal taxes; and certainly more and better trained fish biologists and fish-culturists; all must be employed to keep angling our most popular form of outdoor recreation.

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REPORT OF THE DIVISION OF PROTECTION AND LEGISLATION

ELLIOTT S. BARKER

Perhaps the most important legislation during the past year affecting the fisheries activities of the various states was federal rather than state legislation. I refer to the Dingell Bill H.R. 1746. Although passed by the House and then by the Senate with a few clarifying amendments, the bill has not yet actually become law. The House must, and undoubtedly will, soon after September 21, when it reconvenes, concur in the Senate amendments and we hope that the President will sign it.

Regarding state legislation, it is to be regretted that replies were received from only 31 of the 48 states to a questionnaire on the subject. Out of these states 17 reported on an increase either in resident or non-resident license fees. Some others had an increase in license fees in 1947. So it appears very evident that there is a trend toward higher fishing license fees generally. That was to be expected and indeed is necessary to keep revenue in balance with increased costs of operation.

A few states report laws enacted by their legislatures during the year which do materially affect the fisheries resources or their administration. For instance, two states were given authority for the Game Commission to establish and regulate the season and creel limits. Of course, all states should have that basic authority. One state was given greater regulatory power through the governor.

Two states, through legislative action, liberalized the taking of rough fish. One provided a continuous open season on crappie. Another similarly removed the size limit on bluegills, sunfish, calico bass, rock bass and perch. To an administrator of a state which has long had the fullest regulatory power it seemed indeed odd that such matters require legislative action.

One state stopped the use of live bait in all waters, and required all non-residents regardless of age to have a license to fish, and limited out-of-state shipments to one bag limit per week. Still another prohibits the use of live bait in waters free of rough fish.

Oregon reports legislation relating to dams on anadromous fish streams was adverse to fisheries interests, while other laws passed governing commercial fishing were favorable to sport fishing, and legislation was provided to allow more flexibility in regulations. On the other hand, Washington reports favorable legislation by making all tributaries of the Columbia River below Bonneville Dam spawning sanctuaries for anadromous fishes.

Either by legislative action or by regulations of the commissions there seems to be a definite trend toward lengthening the seasons and removal of size limits on warm-water or spiny-rayed fishes and shortening of trout seasons.

Not so much through legislative action but rather by policy, response to our questionnaire indicates a trend toward more investigational work by fishery biologists, toward eradication of rough fish as a means of improving fishing, and toward acquisition and development of fishing waters for the benefit of the public.

REPORTS OF STANDING COMMITTEES

COMMITTEE ON INTERNATIONAL RELATIONS

Albert M. Day

General Summary

The past year has been one of greatly increased interest and activity in relation to the fisheries of the world. As in the political field, isolation of national interest and viewpoint is no longer possible or desirable. Increase of the world population, with the resulting increased demand for food, particularly the proteins and vitamins which come from the sea, has quickened interest in exploitation of the marine resources. New problems have arisen, and old ones have become more urgent.

It is gratifying to note that conservationists are alert to the dangers of uncontrolled exploitation. Since the last meeting of the Society, there have been three international conferences concerned with the conservation of natural resources, primarily of renewable resources. Although the deliberations have led to no definite action, they have tended to clarify and unify the thinking of scientists and administrators over a large part of the world.

There is great interest in the question of rights and responsibilities in the important fishing areas, particularly in areas available to the fishermen of two or more nations. Definite progress has been made toward the solution of some of the problems arising from conflicting interests. Eleven nations of North America and Europe recently signed an agreement respecting the fisheries of the northwestern part of the Atlantic Ocean. The United States has entered into an agreement with Mexico, and another with Costa Rica, providing for the investigation of the valuable tuna resources. It may be expected that these two tuna agreements providing only for investigation will lead to more comprehensive agreements in the future, adding the function of international regulation.

The capture and conservation of fishery products are not the only problems of growing concern. The unsettled conditions surrounding monetary exchange have led some nations to seek foreign markets for their surplus fish, and, at the same time, to protect their own markets from imported products of lower price. In an attempt to improve their fiscal position, some countries have subsidized the fishing industry to permit increase of production for export. Here is a serious problem for which a solution is not evident, and it is doubtful that any solution will be completely satisfactory to all concerned.

Many of the activities of the Fisheries Division of the Food and Agricultural Organization of the United Nations are directed toward a more orderly development of the fishing industry of the world, so that production will increase and distribution be made according to needs. The Organization is encouraging the establishment of regional fishery councils to permit consideration of problems peculiar to limited geographical areas. The Indo-Pacific Council was organized early in 1948 and held its inaugural meeting in March, 1949. A meeting to consider the establishment of a Mediterranean Council was convened at Rome in late August of 1949. We may expect similar groups in other parts of the world.

The United States Government, through the Interdepartmental Committee for Scientific and Cultural Cooperation, continues to assist other American Republics by exchange of experts in various fields and by the training of qualified students in educational institutions and fishery research laboratories of this country. Authority exists for extension of this kind of cooperation to other areas of the world, but funds have not been made available for the increased activity. The President of the United States, in "Point Four" of his inaugural address on January 20, 1949, proposed a far-reaching plan for the economic advancement of undeveloped areas of the world. The program would enlist the assistance of international and private organizations in addition to agencies of the Government. A great amount of effort has been expended on preliminary planning for this Point Four Program, and we may confidently expect the emergence of a program of great value to nations which have not fully developed their resources. It is recognized that fisheries commonly yield a high and immediate return for a relatively modest investment. For that reason, the program will doubtless provide for fishery development in many areas which give promise of increased yield. Rearing of fishes in ponds will also receive special attention. The United States Government is already intimately concerned with fishery investigation or administration in the Trust Territory, the Philippines, and Japan.

The following sections of this report are devoted to a detailed account of international activities in the field of fisheries during the past year. The increasing importance of fishery resources in domestic and foreign commerce emphasizes the continuing need for a Committee on International Relations of the AMERICAN FISHERIES SOCIETY. Members of the Committee should be alert to all developments of interest to the Society, so that the annual report will reflect accurately the changing world conditions.

INTERNATIONAL CONFERENCES

Inter-American Conference on Conservation of Renewable Natural Resources.—This international conference was held at Denver in the period from September 7 to 20, 1948. Each of the 21 countries in the

Organization of American States (formerly the Pan-American Union) was represented by a delegation, and Canada sent a group of observers. The central theme of the conference was the conflict arising from increasing populations and decreasing productivity in foods. Emphasis was placed on the need for conserving the basic land and water resources, and developing new sources of food. There is no doubt that the meeting served a valuable function in bringing together on a common ground many of the leading scientists and administrators concerned with conservation in the Western Hemisphere.

United Nations Scientific Conference.—The United Nations Scientific Conference on the Conservation and Utilization of Resources was held at Lake Success, New York, in the period from August 17 to September 6, 1949. The Conference was devoted to an exchange of ideas and experience on the techniques of resource conservation and use, their economic costs and benefits, and their inter-relations. Meetings for presentation of scientific papers were held on 12 days, with five sections in session simultaneously, dealing with water, land, forests, minerals, fuel and energy, and fish and wildlife. Participants were selected from a panel of competent authorities on a wide geographical basis. Topics covered in sessions devoted to fish and fisheries were: changes in abundance of fish populations, developing fishery resources, fishery statistics, management of fresh-water fish, technological development in fisheries, and research on marine resources.

International Union for the Protection of Nature.—The Union was formed at a meeting held at Fontainebleau, France, from September 30 to October 7, 1948, although the movement of which it was born can be traced for many years. The 1949 meeting was held at Lake Success concurrently with the United Nations Scientific Conference, during the period from August 22 to September 1. The meetings of the Union considered a wide variety of important problems concerned with the protection of nature in all parts of the world.

International Council for the Exploration of the Sea.—Three United States observers attended the annual meeting of the International Council for the Exploration of the Sea, at Copenhagen, Denmark, October 4 to 11, 1948. The observers were Dr. W. M. Chapman, Department of State; Dr. L. A. Walford, Fish and Wildlife Service; and Charles E. Jackson, National Fisheries Institute. The Council is an association of 13 nations organized to promote international fishery research, chiefly marine; to provide means of collaboration among scientists; and to exchange information.

At the 1948 meeting, 96 scientists representing the member nations were present. In separate committee meetings, they reportd the year's progress of researches in the several areas within the scope of the Council, and recommended the course of the next year's studies. In addition, two special scientific meetings were held, one on climatic changes in the Arctic in relation to plants and animals, the other on the comparative efficiency of fishing craft and fishing gear. The proceedings of all the committee meetings, as well as of the plenary sessions, are being published in *Rapports et Procès Verbaux des Réunions,* Vol. CXXIV.

Subsequent to the meeting at Copenhagen, the Council set up the Atlantic Committee for the Study of Tunas, which met at Malaga, Spain, May 23 to 27, with Dr. L. A. Walford as the United States observer. The general purpose of the Committee was to assemble all knowledge about tunas, and to plan and coordinate tuna research. Since tuna studies cannot be effective without international collaboration, the Committee planned to assemble tuna literature and assess the present store of knowledge about tunas; to review biometric methods as applied to tuna studies; to limit its work to certain species of tunas; and to consider means of organizing tuna research on an international scale.

UNITED STATES COOPERATION WITH AMERICAN REPUBLICS

The Interdepartmental Committee on Scientific and Cultural Cooperation was created by the President in May, 1938, to facilitate the solution of problems of common interest to the peoples of the American Republics. The Congress, through enactments in 1939, authorized the conduct of cooperative programs and the exchange of technical specialists. The United States Information and Educational Exchange Act of 1948 extended the authorization to almost all nations of the world, but no funds have been appropriated to implement the extension. The program of scientific and cultural cooperation has been highly successful in bringing about an exchange of information and techniques, and increasing the understanding among peoples of the Western Hemisphere.

President Truman, in his inaugural address of January 20, 1949, stated that the United States should make available American scientific and technical knowledge to underdeveloped areas of the world and should encourage capital investment in those areas to help achieve peace, plenty, and freedom. Plans for implementation of this so-called Point Four Program are still in the formative stage, but it is expected that a greatly expanded program of cooperation will emerge in the near future.

Fishery Mission to Mexico.—The Fishery Mission to Mexico, established in 1942, was extended for a two-year period in 1948. The most significant development of the past year was the signing of a fishery convention by Mexico and the United States at Mexico City on January 25, 1949. The agreement establishes an international commission responsible for the scientific investigation of tuna, as related in greater detail elsewhere in this report. The Mission was instrumental in assembling the scientific and technical information essential to successful negotiation of the treaty.

During the past year, the Chief of the Mission prepared and published a critical analysis of the marine fishery situation in Mexico. The report was widely distributed and favorably received. The market for domestic consumption of fishery products in Mexico is small, and about two-thirds of the edible products are taken by foreign boats, or by Mexican boats for export. There appears to be ample opportunity for further exploitation of the sardine and mackerel of the Pacific Coast, with consequent reduction in price to the consumer.

A movement is now under way to establish an institute for scientific study of the shrimp resources of the Pacific coast of Mexico. In the inland waters, emphasis is being placed on the development of farm ponds for warm-water species. A detailed account of the Mission was published in Volume 78 of the TRANSACTIONS.

Fishery Mission to Venezuela.—In August, 1947, negotiations were completed between the Governments of Venezuela and the United States for assignment of a fishery biologist to conduct marine investigations, with special attention to the biology of sardines in the Gulf of Cariaco. Field work of the project began in February, 1948, and continued for a year.

A marine fishery laboratory was established at Caiguire, on the Gulf of Cariaco, and a 65-foot vessel assigned to the project. Statistical and biological studies of the sardines of the Gulf of Cariaco showed that the population was a migratory one, and that the fluctuations in abundance were not subject to full control by restrictive measures applied in the Gulf of Cariaco. A series of experiments carried out in Lake Maracaibo yielded information on the damage to fisheries as a result of proposed underwater seismographic exploration explosions. A report on this work, with recommendations for minimizing the damage, has been submitted for early publication. Management and conservation measures respecting pearl oysters and the cockle *(Arca occidentalis)* were prepared for the Ministry of Agriculture.

Close cooperation was maintained with the management of Pesquerias Caribe, a commercial fishing enterprise financed jointly by the Venezuelan Government and the Venezuela Basic Economy Corporation. Although the project was terminated in February, 1949, many problems remain to be solved, and there is a possibility that it will be reactivated in the future

Fishery Mission to Peru.—In May, 1949, in response to a request from the Peruvian Government through the Institute of Inter-American Affairs, the Fish and Wildlife Service assigned an aquatic biologist for a period of two months to assist in the reorganization of the agency which administers the fish and wildlife resources of the country. Costs of the mission were met in part by the Institute of Inter-American Affairs. The mission was outstandingly successful in reaching the primary objective, and in assisting the Government in planning a wholesale fish terminal, a technological and biological laboratory, collection of biological and production statistics, and compilation of laws and regulations relating to fish and game.

Plans are being made for reassignment of the biologist for a longer period, and for assignment of other experts to assist in special phases of fishery development. The ultimate aim of the program is to increase the domestic consumption of fishery products, and there is good reason to believe that this will be realized in large measure.

In-service Training Grants.—The Fish and Wildlife Service continued its program of training qualified students of other American Republics in several phases of biological science and management in relation to the conservation of fish and wildlife resources. Grants are offered in fish culture; fishery biology, agriculture, fishery economics, fishery technology, general wildlife conservation and management, management of injurious wildlife, and fur-resource technology. The training period usually covers one year.

During parts of fiscal year 1949, six students were engaged in training, one in fishery technology and the remainder in fishery biology. Two were from Brazil, two from Peru, and one each from Costa Rica and Colombia. It is gratifying to note that the students selected are outstanding personally and scholastically, and that they profit greatly from the program of instruction offered. Many have assumed positions of high responsibility in conservation work upon return to their home countries. Twenty-four students have received training since the program started in 1942.

Grants-in-aid to Specialists.—The Department of State continued its program of awarding travel grants to scientific and cultural specialists. Awards may be made to nationals of American Republics for travel in the United States, or to citizens of the United States for travel in the American Republics. Most of the grants are made to foreigners. During fiscal year 1949, three awards were made, in cooperation with the Fish and Wildlife Service, to persons interested in fisheries or in general conservation of renewable natural resources.

Dr. José Alvarez del Villar, Professor of Zoology in the Escuela Nacional de Ciencias Biológicas, Mexico, spent three months of study and investigation in the Scripps Institute of Oceanography, and in visits to other biological laboratories. Mr. Luis Macias Arellano, Chief of the Game Department, Ministry of Agriculture and Livestock Production, Mexico, devoted a four-month stay primarily to a study of management of migratory waterfowl. Dr. Leonce Bonnefil, Chief, Section of Zoology and Entomology, Department of Agriculture, Haiti, arrived in the United States in June to visit numerous laboratories and universities over a period of three months.

In addition to visitors of this planned program, the Service is host to numerous foreigners who come to the United States for short periods of observation, or for instruction in methods of administration and research. For the most part, these visitors are mature in basic training and experience, but desire to learn how problems are handled in the United States. A valuable feature of the visits is that they permit investigators and administrators in the United States to obtain detailed knowledge of conservation problems in the other countries of the world.

PHILIPPINE FISHERY PROGRAM

The objectives of the Philippine Fishery Program, together with information on the means employed to attain them, have been presented in detail in earlier reports of this Committee. Accordingly, the present report is limited to a record of progress made in realization of the objectives.

Training Program.—The Fish and Wildlife Service has authorization to train in the United States not to exceed 125 Filipinos in fishery industry and science. At the end of June, 1949, 101 persons had entered the one-year training period, and it is expected that the entire program will have been completed by September, 1950. The trainees have demonstrated great aptitude and diligence in training, and have derived full benefit from the opportunity to learn the modern methods employed in this country. The increasing body of trained technicians serves as a firm basis for optimism concerning orderly development of the fishing industry in the Philippines. Returning trainees have been employed readily by industry or by the Philippine Bureau of Fisheries, and have assumed positions of responsibility.

Scientific and Technical Program.—Fishing projects on an experimental and exploratory basis have demonstrated conclusively that the fisheries of inshore waters near Manila cannot yield supplies of edible fish adequate for domestic demands. In all probability, over-fishing, particularly destructive fishing with dynamite, has contributed largely to the continued low yield from those areas. There is need for more intensive exploitation of the more distant inshore areas and of the offshore waters. Progress has been made in increasing the use of otter trawlers, but fishing far from shore by long-line trolling and with bait and jigs has not been successful on a commercial scale. Nevertheless, experiments are being continued in the hope of discovering improved methods and more ample sources of bait fishes.

Studies have been made of marketing conditions in several provinces, with special reference to the kinds and abundances of fishes, transportation and preservation facilities, prices, and other factors which bear upon distribution and consumption of the fresh products. These important surveys are being continued and expanded.

Oceanographic investigations have yielded a large volume of data on physical, chemical, and biological conditions which determine the basic productivity of the sea. Field investigations continue, and progress has been made in compiling, tabulating, and analyzing the data preparatory to the publication of comprehensive reports. Conditions in the sea near the Islands are extremely complex, and the short-term studies under the Program are not sufficient to solve all of the problems encountered.

Those studies will serve as a point of departure for future investigations to be conducted by the Philippine Bureau of Fisheries as part of its continuing research program.

The program of investigation of the rearing of Bangos (milk fish) in ponds was hampered by destructive typhoons in 1947, but the facilities have been replaced, and increased in some areas. There are opportunities for great expansion of production of fishes in ponds, and the outlook is encouraging for this important source of low-cost proteins and vitamins.

Technological studies of various phases of the fishing industry required the establishment of a laboratory, net loft, and pilot processing plant. Investigations by the staff have yielded a large amount of information on traditional methods, and have developed new methods which can be adopted profitably. Improved methods in factory processing of fishery products and in home cooking give promise of yielding more wholesome and palatable foods. There is urgent need for continued experimentation in all lines to insure orderly development of the industry from the sea to the ultimate consumer. A number of circumstances conspire to keep the supply of fish low and the price high. The fishing industry cannot attain full development until all of the numerous segments of the industry have also reached full development.

United States Whaling Investigations

In the summer of 1948, a biologist was assigned to the single United States whaling station, located in California, to obtain biological and statistical data on the whales captured and processed, and to make observations on the abundance and distribution of whale populations. Information of this kind is essential as a basis for international regulations designed to conserve and rehabilitate the depleted whale populations.

The biologist devoted two weeks to observations of whaling activities in the area of Vancouver Island, British Columbia, Canada. Also, in response to the request of local interests in Maine, the biologist made a preliminary survey of whale populations in that area. He found significant numbers of whales in the general area of northeastern Maine and the Bay of Fundy, and it is probable that the population is sufficiently large to support a shore whaling station serviced by two killer boats.

Owing to the fact that the whaling station in California did not operate in the summer of 1949, the biologist devoted the usual field period to bibliographic and statistical research in Washington.

International Whaling Commission

The International Agreement for the Regulation of Whaling signed at Washington, December 2, 1946, entered into force on November 10,

1948. The first meeting of the International Whaling Commission, established under the authority of that convention, was held at London from May 30 to June 7, 1949. The following governments who have ratified or adhered to the 1946 Convention were represented by Commissioners: Australia, Canada, France, Iceland, Netherlands, Norway, South Africa, Sweden, United Kingdom, United States of America, and U.S.S.R. The following governments and organizations were represented by observers: Argentina, Brazil, Chile, Denmark, New Zealand, FAO, and SCAP.

The United States Delegation consisted of Dr. A. Remington Kellogg, Director of the U. S. National Museum, Commissioner; who was assisted by Dr. H. J. Deason, Chief of the Office of Foreign Activities, Fish and Wildlife Service; and Mr. Charles I. Bevans, Office of the Legal Advisor, Department of State, as advisors.

The Canadian Delegation was composed of Dr. Stewart Bates, Deputy Minister of Fisheries, Commissioner; and Dr. Wilfred Templeman, Fisheries Research Board of Canada, Advisor.

Officers of the Commission elected to serve for a term of three years are Dr. B. Bergersen (Norway), Chairman; Dr. A. Remington Kellogg (U. S. A.), Vice Chairman; and Mr. A. T. A. Dobson (U. K.), Secretary. Much of the time of the Commission was spent in organizational matters, including the drafting of rules of procedure. Amendments were made to the International Whaling Regulations contained in the Schedule annexed to the 1946 Convention. The pelagic whaling season for the Antarctic was altered from December 15 to April 1, and effective for the 1949-50 season will become December 22 to April 7. The total ban on the taking of humpback whales south of 40° South Latitude was relaxed to the extent that in each of the whaling seasons 1949-50 and 1950-51 a maximum of 1,250 humpback whales may be taken in that area. Paragraph 10 of the Schedule dealing with the conditions for the operation of land stations and whale catchers attached thereto was revised in the interest of clarity. Likewise, Paragraph 17 of the Schedule, which specified conditions under which factory ships may operate solely within certain territorial waters, was revised in the interest of clarity. The Commission will hold its next meeting at Oslo, Norway, beginning July 15, 1950.

Fisheries of the Trust Territory

The Department of State announced on September 9, 1948, the policy of the United States Government relating to commercial fishing operations in the United States Trust Territory of the Pacific Islands (the former Japanese Mandated Islands). The policy was approved by the Departments of State, Army, Navy, Air Force, and Interior as a guide to the administration of the Trust Territory, and will have the effect of opening the area to commercial fishing. Rich fishery resources, particularly tuna, are available in the waters around this Territory in an area as large as the continental United States. The Territory itself contains scarcely as much land area as the State of Delaware. Several commercial fishing companies have shown interest in fishing operations. It is possible that an industry can be built on the fishery resources that will eventually pay a part of the administrative cost of the Territory.

Fishing operations will be under the strict control of the High Commissioner of the Trust Territory in order that the welfare of the native inhabitants can be safeguarded and the harvesting of the resources can be undertaken along adequate conservation lines. The High Commissioner will look to the Fish and Wildlife Service for advice on regulations, and for such statistical and research services as may be necessary.

Fishing opportunities will be equally available to the fishing enterprises of all nations except that the High Commissioner will have discretion in excluding enterprises for reasons of security or for the purpose of carrying out the obligation to promote the advancement of the inhabitants.

International Fishery Agreements

During the past 25 years the success of international agreements providing for the investigation and management of fishery resources of the high seas of interest to more than one nation has led to the application of the international agreement approach to other fishery problems during the current year. The Fish and Wildlife Service has cooperated actively with the Department of State in the preparatory work and in the actual negotiations.

The International Convention for the Northwest Atlantic Fisheries was concluded on February 8, 1949, by the United States, Canada, Denmark, France, Iceland, Italy, Newfoundland, Norway, Portugal, Spain, and the United Kingdom. The United States delegates were Dr. W. M. Chapman and Dr. W. E. S. Flory, Department of State; Dr. H. J. Deason, Fish and Wildlife Service; and Mr. Frederick J. Zimmerman, Atlantic States Marine Fisheries Commission. They were assisted by advisors representing various U. S. Government agencies, the fishing industry, and the New England States.

The Canadian delegate was Dr. Stewart Bates, Deputy Minister of Fisheries; his alternate was Dr. A. W. H. Needler, Assistant Deputy Minister of Fisheries; and they were assisted, as advisors, by Mr. F. M. Tovell of the Department of External Affairs and Messrs. S. V. Ozere and F. H. Woodring of the Department of Fisheries. The Newfoundland delegate was Mr. Raymond Gushue, Chairman of the Fisheries Board of Newfoundland, and Dr. Wilfred Templeman was his advisor.

The principal feature of the agreement is the provision for the establishment of an international commission composed of not more than three commissioners representing each signatory government. The commission shall have the power of conducting investigations, which shall be carried out primarily by fishery research agencies of the contracting governments working on a cooperative basis, and of recommending regulations for the conservation of the fisheries which are to be implemented by each government in respect of its own nationals and vessels. The area covered by the Convention is all waters of the Atlantic Ocean west of 43° West Longitude and north of 39° North Latitude to the intersection of 78° 10′ North Latitude with the west coast of Greenland.

Through the medium of this international body it will be possible to keep under continuous biological and statistical review the fisheries of the Northwest Atlantic. When necessary, regulations can be adopted in the interest of conservation that will apply to all vessels operating in the area. Because the Northwest Atlantic fisheries are international, regulation, although urgently needed for certain species, has been considered impractical because the fishermen of no one nation would agree to the imposition of regulations, as fishermen operating on the same grounds were not subject to the same regulations.

The Convention between the United States and Mexico for the establishment of an International Commission for the Scientific Investigation of Tuna was signed at Mexico City January 25, 1949. It was negotiated and developed at a conference held October 25 to November 4, 1948, in Mexico City by the following delegations. For the United States: *Delegates:* W. M. Chapman and Paul J. Reveley, Department of State; Hilary J. Deason, Fish and Wildlife Service; *Advisors:* Richard Croker, California Bureau of Marine Fisheries; Miss Isla V. Davies, Department of State; Milton J. Lindner, Chief, U. S. Fishery Mission to Mexico; Arnie J. Suomela, Oregon Fish Commission; Richard Van Cleve, School of Fisheries, University of Washington; *Secretary:* Taylor G. Belcher, American Embassy in Mexico; *Assistant Secretary:* Miss Janet Park, U. S. Fishery Mission to Mexico.

For Mexico: *Delegates:* Roberto Córdova, Ambassador of Mexico, Chairman; Manuel J. Sierra, Minister of Treasury and Public Credit; Enrique Villegas Bustamante, Director General of Fisheries and Allied Industries of the Ministry of Marine; Leonardo Pasquel, Ministry of Economy; *Advisors:* Roberto Arroyo Carrillo, Technical Commission of the Directorate-General of Fisheries and Allied Industries; Fernando Robert, Ministry of Treasury and Public Credit; Antonio Cobos, Ministry of Economy; Armando C. Amador, Envoy Extraordinary and Minister Plenipotentiary of Mexico; *Secretary:* Cesar Supulveda.

While the agreement provides only for investigations, the negotiators felt that, since the tuna fisheries have not previously been studied exhaustively, considerable knowledge should be accumulated on an international basis before any international device for regulation is established.

A Convention between the United States and Costa Rica for the establishment of an Inter-American Tropical Tuna Commission was signed at Washington on May 31, 1949. The agreement is open to adherence by other interested governments.

The Convention was negotiated for the United States by: *Delegates:* W. M. Chapman, Department of State; and M. C. James, Fish and Wildlife Service; *Advisors:* Donald J. Chaney, Fish and Wildlife Service; Richard Croker, California Bureau of Marine Fisheries; Arnie J. Suomela, Oregon Fish Commission; Warren F. Looney, Fred G. Heins, and Fred E. Taylor, Department of State; and Frederick J. Cunningham, American Embassy, San Juan, Costa Rica. The delegation for Costa Rica consisted of: *Delegates:* Mario A. Esquivel, Costa Rican Ambassador to the United States; and Jorge Hazera, Counsellor of the Costa Rican Embassy; *Advisors:* José Luis Cardonna-Cooper and Eduardo Martin.

The Convention is similar in purpose and objectives to the agreement between the United States and Mexico.

The Northwest Atlantic Convention was ratified by the President of the United States on September 1, 1949, and will enter into force when ratifications have been received from three additional signatory countries. The tuna convention between the United States and Mexico was ratified by the President on August 30, 1949, and will enter into force upon ratification by Mexico. The tuna convention between the United States and Costa Rica was ratified by the President on September 1, 1949, and ratification by Costa Rica is necessary for entry into force.

No action has been taken, since the 1948 meeting, toward ratification of the International Convention for the Great Lakes Fisheries signed by the United States and Canada on April 2, 1946.

International Fisheries Commission

The Commission is composed of Edward W. Allen and M. C. James for the United States; and Dr. Stewart Bates and G. W. Nickerson for Canada.

During 1948, the International Fisheries Commission, commonly known as the Halibut Commission, encountered new problems arising from the fact that the halibut season has grown progressively shorter, being compressed to about 60 days. The halibut season is the period required by the fleet to take the total catch quota, which in 1948 was 54 million pounds. Such a period of fishing is undesirable from a biological standpoint, in that it does not provide for full utilization of halibut stocks, and also has economic repercussions. In recognition of these difficulties, the Commission proposed for the 1949 halibut season a "split season" arrangement which would apply limitations upon the fleet in such a way as to extend the season for at least 60 additional days. This proposal, publicized in January, 1949, was met with serious objections from portions of the Alaska halibut fleet and others in the Territory. As the result of incomplete understanding of its provisions, and the disagreements as to its practicality and desirability, the Commission withheld application of this provision, and the 1949 regulations were substantially identical with those in effect in 1948.

The halibut stocks continue to be in a healthy condition and there is indication that some increase in catch could be permitted if the season could be adjusted. The halibut industry has requested a number of modifications in the treaty, designed to accomplish the foregoing purpose and to vest clearer authority in the Commission. The United States Government and the Canadian Government have been considering these recommendations informally, but no steps toward negotiating a new treaty have been taken. The Commission has scheduled public hearings for September and October 1949 at Seattle and various points in British Columbia and Alaska for the purpose of obtaining public reaction to adjustment of the fishing season and other Commission responsibilities, including treaty revision.

International Pacific Salmon Fisheries Commission

The Commission is composed of Messrs. Albert M. Day, Edward W. Allen, and Alvin Anderson for the United States; and Messrs. Tom Reid, Olaf Hanson, and A. J. Whitmore for Canada. Mr. B. M. Brennan, Director of the International Pacific Salmon Fisheries Commission, suffered a fatal heart attack at his home in Blaine, Washington, on August 14, 1949. He was one of the original commissioners, being one of the three American members appointed by President Roosevelt in 1937.

The success of the program inaugurated by the International Pacific Salmon Fisheries Commission has begun to demonstrate itself in the number of fish taken in the fishery. The Canadian catch of sockeye salmon for the 1949 season was 1,009,000, and the United States catch 1,049,000, approximately. This is a large increase over the take in the cycle year of 1945. If suitable restocking of some of the upper reaches of the Fraser River can be accomplished, it appears that the fishery can be restored to its former healthy condition and perhaps even increase the annual yield.

One of the important features in the restocking program this year was the establishment and initial operation of the Quesnel Field Station. Eggs numbering 270,000 from the native Horsefly River run have been placed in the Field Station for incubation, hatching, and eventual rearing. The resultant fingerlings will be marked and returned to their native stream as a controlled experiment to determine if the native run can be artificially handled and successful returns obtained. This experiment is a necessary adjunct to any transplantation operation. From the Seymour River, located at the head of Shuswat Lake, 160,000 eggs have been transported by air to the Station for eventual transfer as fingerlings to Upper Adams River. The migration distance from salt water to each spawning area is the same, and the temperatures at spawning time are approximately the same. The drainage areas of the Seymour and Upper Adams Rivers are similar, both having a partial glacial source of water.

One of the disturbing elements in connection with the Fraser River run has been the proposal of the Aluminum Company of Canada to construct hydroelectric power facilities in the Chilko Lake area of British Columbia. This, if approved, would probably destroy one of the most important producing areas in the entire Fraser River system. The Commission has voiced its opposition to this proposal through the Canadian Government, and it appears likely that, as a result of the opposition of the fishing interests, the impoundment will be made elsewhere on a tributary that is not important for spawning purposes.

ECONOMIC COOPERATION ADMINISTRATION

In March, 1948, Mr. Robert A. Nesbit joined the American Mission for Aid to Greece, to undertake a brief study of the fishing industry of that country. In July, he transferred to ECA, and the period of investigation was extended to July 1, 1949.

A number of unfavorable conditions have made the industry ineffective in supplying the proteins of low cost for the dietary requirements of the Greek people. The trawler fleet is underpowered, so that the more accessible shoal waters are overfished, and the offshore waters neglected. Nets of very small mesh are used to take the adults of several species of small size; but, at certain places and seasons, the nets also take the young of other species. There is need for control of fishing intensity with respect to gear, areas, and seasons. At present, only trawlers with power units of 85 H.P. or more are being licensed, with the purpose of diverting activity to the offshore waters. Purse seines are taking some sardines, mackerel, and tuna, but there is need for more complete exploitation of these pelagic forms.

The marketing of fishery products has been inefficient and wasteful. There is urgent need for improved port facilities, ice plants, roads, and vehicles to insure prompt delivery of the products in good condition. Much has been done in this direction, particularly by making credit available, and it is expected that the improvement will continue.

The newly established Hydrobiological Institute is cooperating with the Ministry of Mercantile Marine in the collection of biological and production statistics.

FOOD AND AGRICULTURE ORGANIZATIONS OF THE UNITED NATIONS

The FAO Conference held in Washington in November, 1948 approved a program which included, in particular, continuation of the collection of information on commodity standards for fishery products and the preparation of a report thereon to member governments, and the initiation of preparatory work looking toward the establishment of a fisheries council "in each region or, in the light of all circumstances, may be deemed appropriate by the Director General." It was further resolved that FAO should assist governments to improve inland and coastal fisheries and should help in the supply of requisites essential for fisheries production.

Advisers on fisheries to the Canadian members of FAO at the 1948 meeting were Dr. [illegible] of the Department of Fisheries and [illegible] J. Morrow of the Fisheries Council of Canada. The Mexican adviser on fisheries was Manuel L. [illegible], Ministry of the Treasury and Public Credit. The United States advisers on fisheries were: Andrew W. Anderson, Fish and Wildlife Service; W. M. Chapman, Department of State; Edward W. Allen, Seattle, Washington; Charles E. Carry, National Canners Association; Schuyler Otis Bland, Chairman, Committee on the Merchant Marine and Fisheries, House of Representatives; and Charles E. Jackson, National Fisheries Institute.

During the past year FAO's Fisheries Division has published an excellent Yearbook of Fisheries Statistics and a periodic Fisheries Bulletin. Technical aid has been rendered a number of countries and preparations are under way for a publication of fishery abstracts to be issued in several languages. The Indo-Pacific Fisheries Council was established at a meeting in Singapore in March. Earlier, the Baguio Agreement was accepted by the United States, and it is now a member of the Council.

A commodity study on salmon was completed during the year, and studies on herring and tuna begun. In connection with the herring study, a technical conference of government and industry experts was held at The Hague late in August to discuss packing, processing, marketing, and economic problems. A meeting which may lead to the establishment of a Mediterranean Fisheries Council is scheduled for September 19. The United States will participate in this meeting only as an observer, for it has neither territorial nor fishing interests in the area.

Indo-Pacific Fisheries Council

On November 9, 1948, the agreement concluded at Baguio, Philippines, February 26, 1948, became effective by reason of its approval by five of the participating governments. The first meeting was held at Singapore, Straits Settlements, March 24-31, 1949, and was attended by delegates from Australia, Ceylon, China, France, India, Netherlands, Philippines, United Kingdom, and United States of America, and by observers from Burma, SCAP, South Pacific Commission, and UNESCO. The Secretariat pursuant to the agreement was provided by FAO.

The United States delegation was composed as follows: O. E. Sette, Delegate, Pacific Oceanic Fishery Investigations, Fish and Wild-

Service; W. E. S. Flory, *Alternate Delegate,* Department of State; and *Advisors:* Hilary J. Deason, Chief, Office of Foreign Activities, Fish and Wildlife Service; Charles Butler, Chief Technologist, Pacific Oceanic Fishery Investigations; Herbert E. Warfel, Chief, Biological Investigations, Philippine Fishery Program, Fish and Wildlife Service.

The sessions of the Council were devoted to the development and approval of Rules of Procedure, the presentation of reports on the status of fishery research programs of member governments, and to a symposium on pelagic fisheries. Provision in the Rules of Procedure was made for the establishment of two standing committees: (1) Biology and Hydrology, and (2) Technology.

At the final session, the Council referred to the standing committees problems to be investigated and reported on at the 1950 meeting: (1) To explore the possibility of collaboration of member governments in study of the tuna, herring-like and mackerel-like fisheries; (2) To explore the opportunities for collaboration of member governments in fish culture of fresh-water and salt-water species; (3) To explore the possibilities of the cooperation of member governments in the compilation of descriptive catalogues of indigenous fishing gear and fish processing methods, with a view toward laying the foundation for future work by the Council in the modernization and improvement of such methods. The next meeting of the Council is tentatively scheduled to be held in Australia during March, 1950.

Administration of Japanese Fisheries

In response to an invitation by the Supreme Commander for the Allied Powers, a special mission was sent to study the Japanese fisheries in April 1949. Members of the Mission were: Edward W. Allen of Seattle, U. S. Commissioner, International Fisheries Commission; Frederick M. Bundy, Gloucester, Massachusetts; and Donald P. Loker, Terminal Island, California, both of whom are executives of fishing companies.

The Mission made a comprehensive study of Japanese fisheries, and the findings have been published in a report of considerable interest to persons concerned with the fisheries of the Pacific. The fishing industry is extremely important to Japan as an industry and as a source of food. About one million persons gain their livelihood from the industry, 400,000 boats are used, and the annual production reaches approximately six billion pounds. Contrary to general opinion, the coastal fishery is more important than the pelagic fishery. After the war, the Japanese fishing fleet was greatly overbuilt and should be reduced in size. The report points out that fishery research in Japan has been directed primarily toward further exploitation of the natural resources, rather than toward conservation and maintenance of a sustained yield.

The report commends SCAP for excellent leadership by the Natural Resources Section and its Fisheries Division; for its policy aimed at maximum sustained production; for its careful supervision of the distribution of gear and oil; and for its firm attitude concerning expansion of the Japanese fishing area. The report opposes any plan which will permit future Japanese fishing in the coastal waters of any of the Allied Powers, and opposes subsidy of export, and dumping of fishery products for purposes of monetary exchange. It proposes SCAP support of the plan to advance the Japanese Fisheries Agency to cabinet status; patrol of fishing areas by the Japanese Government, supervised by SCAP; and points out the need for close liaison between SCAP and the United States Government and its agencies primarily concerned with fisheries. Finally, the report emphasizes that, when the peace treaty is negotiated, permanent fishery treaties should be negotiated concurrently, and that they should include provision for protection of world coastal fisheries, sound policies for high-sea fishing, adherence to the International Whaling Convention, a fur seal convention, and general respect for all international fishery conventions.

COMMITTEE OF STATE AND NATIONAL RELATIONS

John Van Oosten

The primary function of the Committee on State and National Relations is the consideration of interstate and national-state fishery problems. It is obvious that a consideration of all such problems here is out of the question. In order to restrict our report to a reasonable length we must select only those co-operative developments in the fisheries that may have some general interest for our membership. By this process of selection we shall no doubt overlook certain worth-while projects in some sections of the country.

In general it may be said that no revolutionary upheavals have occurred during the past year to mar the peaceful relations between the fishery interests of the different states or between those of the national government and the states. In fact the tendency has been toward a progressively greater co-operation among the government agencies. The excellent co-operation which has existed between the states and the federal government in the matter of fishery management and stocking programs has continued. Increasing emphasis is being placed on the curtailment of wasteful stocking, and greater efforts are being made to assure a higher return to the creel. Studies are being continued to determine more adequate stocking rates and methods of managing a fishery. Intensive study is also being given to the problems of reservoir fisheries.

Reference should be made here to the newly established Game and Fish Council of Oklahoma which was organized to develop sound fishery and wildlife management practices for impounded waters and watersheds. Through a memorandum of agreement a co-operative program was initiated by the Army Corps of Engineers, the Oklahoma Cooperative Wildlife Research Unit, Oklahoma Agricultural and Mechanical College, the Oklahoma Game and Fish Department, the U. S. Fish and Wildlife Service, and the Wildlife Management Institute.

Another important event was the birth on July 16, 1949, at Mobile, Alabama, of the Gulf States Marine Fisheries Commission, a brother or sister, I am not sure which, of similar commissions established on the Atlantic and Pacific coasts. The new-born commission includes representatives from Florida, Alabama, Mississippi, Louisiana, and Texas. The compact ratified by Congress and signed by the President on May 19, 1949 (Public Law 66), designated the Fish and Wildlife Service as the primary research agency of the Commission.

Initial implementation of the compact was provided in Public Law 163, 81st Congress, which authorized transfer from the Reconstruction Finance Corporation to the Fish and Wildlife Service of two ships, the *Alaska* and *Oregon,* for co-operative fishery work in the Gulf. The *Alaska* will be outfitted as a sea-going marine laboratory for studies of the biological and oceanographic phases of Gulf-fishery problems. The *Oregon* will be outfitted with commercial and experimental gear for Gulf-wide exploratory fishing.

Progress may also be recorded for the so-called River Basin Studies. It may be recalled that the office of River Basin Studies of the Fish and Wildlife Service was organized in 1945 under the provisions of Public Law 732 to conduct special studies of the effects on fish and wildlife resources of federal flood control, channel improvement, hydroelectric power development, irrigation, and drainage projects constructed by the Corps of Engineers, the Bureau of Reclamation, and the Soil Conservation Service, and those water-development enterprises sponsored by states and private individuals.

With its staff of wildlife and aquatic biologists and hydraulic engineers, the Office of River Basin Studies co-operates with the States and the public and private construction agencies, operating under Federal permit, to determine the impact that these projects will have on fish and wildlife populations and habitat. Findings that result from these investigations are required by law to become an integral part of any report submitted to Congress by any agency of the Federal government responsible for engineering surveys and the subsequent construction of such projects.

One of the big river basin projects is that of the Missouri River. Mr. C. N. Feast reported on this project in part as follows:

> For the past year I have been a member of the Missouri River Basin Council, along with I. T. Bode of Missouri, Paul Gilbert of Nebraska, and Harrel

Mosbaugh of the U. S. Fish and Wildlife Service. The purpose of this committee was to make a detailed study of the relationship now existing between the federal water impoundment authorities, the Fish and Wildlife Service and the various states in the Missouri River Basin. On the basis of this study, the committee was to draft a general memorandum of understanding to serve as a working agreement between the federal water impoundment agencies, the Fish and Wildlife Service and the various states, wherein such impoundments had their effect on fish and game resources. In this understanding, of course, were to be included the general principles of the Flood Control Act and Public Law 732, as well as general avenues for operation under the agreement.

I am happy to report that the committee drafted such a memorandum of understanding that was approved, after several meetings among ourselves and with the Reclamation Service, by all of the member states, and I am advised it has been approved by the Reclamation Service. All of the states have signed the document, and it is now in the hands of the Service for their signature.

The document itself recognizes the various jurisdictions of the parties to the agreement and their responsibilities. It includes expressions of the states as to their responsibility toward the development of wildlife and their jurisdiction over the control of wildlife within impoundment project boundaries. It binds the states to confer with the construction agencies concerning project plans and operations, wherein such plans have their effect on wildlife administration. It further binds the states to provide the construction agencies with factual biological information necessary for the formulation and development of proper recreational plans. It binds the U. S. Fish and Wildlife Service to provide similar information. It binds the construction agency to recognize the state agencies as having jurisdiction over the wildlife in the various states of the Missouri River Basin, and the U. S. Fish and Wildlife Service as the official agency with which all transactions and negotiations are to be conducted. It binds the construction agency to permit free and ready access to public areas except for such portion as may be required by the construction agency for purposes of safety, efficient operation or protection of public property, and no private, commercial, or other restrictive right is to be granted which will restrict the general public from hunting, fishing or any other public recreaational use of the project areas, all of this to be consistent with the general plans for area use as mutually agreed upon.

It binds the construction agency to consult with the states and the Fish and Wildlife Service regarding its project area acquisitions, and, in so far as possible, it is to accomplish integration of its land acquisitions with the various states for wildlife management needs. It binds the construction agency to confer with the various states and the Fish and Wildlife Service regarding wildlife problems in the project area, ...

In general, I believe this memorandum of understanding will pave the way for a better relationship between the parties concerned in conformity with the law and in the best interests of the public as a whole.

As far as the Missouri River Valley development is concerned, all the states in the Missouri River Basin have formed the Missouri River Basin Council. The purpose of this Council, aside from the drafting of the memorandum of understanding as outlined above, is to co-operatively endeavor to do everything possible for the proper development of wildlife in the Missouri River Basin, not only on project areas but in other matters of Basin-wide interest. It is true that the first duty of the council was the development of the memorandum of understanding, but no doubt, as time goes on, especially through the Inter-Agency Committee and the Missouri River Basin Survey Division of the U. S. Fish and Wildlife Service, development plans will progressively increase.

We submitted the same memorandum of understanding to the U. S. Army Corps of Engineers. They did not accept it, but submitted to us what they termed a Joint Statement of Policy. In general, it incorporated the same fea-

> tures couched in different language. The Corps of Engineers held that a great many of the clauses incorporated in the memorandum of understanding are now a part of the law and do not have to be referred to. In the over-all, however, the joint statement of policy in its present draft seems to be a trend toward an improvement in relationships between the various states, the Fish and Wildlife Service, and the Army Engineers. This statement of policy is now in the process of being redrafted to conform to the wishes of all parties concerned.

Not much progress has been made on the other so-called "valley authorities." Hearings have been held in both houses of Congress on bills to establish the "Columbia Valley Administration" in the northwestern states, but no decisive action is expected this year since additional hearings have been scheduled in Oregon, Washington, and Idaho after the adjournment of Congress.

Work is, however, going forward in rehabilitating the salmon fisheries of the Lower Columbia River. It may be recalled that the 80th Congress appropriated a million dollars for restoration work on these declining fisheries which now face a serious threat by the construction of numerous dams on the river and its tributaries. Dr. O. L. Meehean reported on the current status as follows:

> To at least partially compensate for the anticipated damage to the fishery, the States of Washington and Oregon, and the Fish and Wildlife Service have undertaken a co-operative rehabilitation program financed by the Federal government. The program includes stream improvement work and the construction of additional hatcheries on the Lower Columbia River tributaries. Construction of the dams on the upper tributaries will necessitate relocation of the runs to the lower portion of the river. Many of the lower tributaries which were formerly used by the salmon have been blocked by dams and log jams. Fish ladders will be constructed over a number of the dams, and stream obstructions will be removed. As a result, many miles of the lower tributary streams will be reclaimed for the use of the salmon and natural propagation. Because of the relatively limited mileage of the lower tributaries, they will be unable to accommodate all of the salmon now using the upper tributaries, and additional hatcheries will be constructed and operated to properly take care of the surplus and assist in the relocation of the runs. Present estimates contemplate that 20 million dollars will be required for the program and that it will require 10 years for completion.

This report would of course not be complete without some reference to the Great Lakes fisheries. As has been customary in the past so again the Great Lakes States, the Province of Ontario, and the Fish and Wildlife Service have joined hands to fight a common enemy and to conduct research on a problem common to all. These joint operations have not been reported to the Society previously so it may be desirable to discuss them briefly at this time.

In 1946, Congress passed a resolution directing the U. S. Fish and Wildlife Service to prosecute "investigations of the abundance and distribution of sea lampreys, experiments to develop control measures, and a vigorous program for the elimination and eradication of sea lamprey populations of the Great Lakes." Soon after the adoption of this resolution there was formed the Great Lakes Sea Lamprey Committee consisting of representatives of all eight Great Lakes States, the province of Ontario, and the Fish and Wildlife Service. This Committee drew up an integrated program of action. Funds for research on and control of the sea lamprey were allocated by Wisconsin, Michigan, Ontario, and the Fish and Wildlife Service. However, much larger appropriations are necessary if more effective controls than are now available are to be applied. A method must be found to destroy the sea lamprey larvae in the mud beds of streams. Some $256,000 has been requested from Congress to expand the co-operative research on this problem; word has been received that an appropriation for this amount has been approved by the Senate, and the bill must now go to conference between the Senate and the House.

The urgency of immediate action is evident from the critical situation that faces the Great Lakes fishing industry today. The Lake Huron lake trout which is the principal victim of the sea lamprey has all but disappeared from the market. From an average annual yield of 1,832,000 pounds over a long period of time, the United States catch has fallen progressively since 1939 to a mere 4,800 pounds in 1948, and the 1949 take will be no better. In Lake Michigan the average annual yield of lake trout has dropped from 6,027,000 pounds to about 1,163,000 pounds in 1948 or one-sixth of normal and conditions in 1949 are even worse.

The second joint investigation on the Great Lakes involves the older problem of the efficacy of artificial propagation of lake trout. Here again a committee, the Great Lakes Trout Committee, was formally organized to develop a program and to follow the results of the experimental work. Minnesota, Wisconsin, Illinois, Indiana, Michigan, the province of Ontario, and the Fish and Wildlife Service are represented on the committee. The primary research consisted of fin-clipping and planting some 411,000 fingerling trout in Lake Michigan in 1944-1946, and some 73,890 in Lake Huron in 1947-1948. Recoveries are being made in Lake Michigan but none so far has occurred in Lake Huron. In addition Ontario fin-clipped and planted some 47,269 lake trout in Lake Superior. A few of these have been recovered.

There are other fishery projects that are being investigated by the joint efforts of states or by the states and the federal government. Time permits only a listing of some of them. Among these may be mentioned the investigations of the Pacific pilchard, the Atlantic salmon, the Green Bay fisheries on Lake Michigan, the "red tide" of the Gulf, and the Atlantic striped bass.

In closing I want to acknowledge by indebtedness for many of the news items in this report to *Outdoor News Bulletin* of the Wildlife Management Institute and to *Conservation News* of the National Wildlife Federation.

EDITORIAL BOARD

Ralph Hile

The reports of this Board at the past three meetings did not make good listening. Members who were gravely concerned over the deterioration of the Society's affairs resulting from continued and unreasonable delays in publication heard only explanations of failure and timid announcements of hoped-for future accomplishment. Be assured that during this period which was so trying to us all, the chagrin of the Editorial Board more than matched the distress of the membership at large.

It is all the more comforting at this time, therefore, to report progress as follows: (1) the distribution of Volume 75 of the Transactions in October 1948; (2) the publication of Volume 76 in February 1949; (3) the completion of Volume 77 early in the present month; and (4) the setting of type for nearly all of Volume 78. This last volume will be mailed to the members near the turn of the year.

These developments signal the final attainment of our goal of bringing our publication schedule up to date, and with it the termination of my own service as Editor—a position taken only on an interim basis and without definite tenure. My successor now can assume his duties without any responsibility for volumes covering past meetings.

Only through the combined efforts of all concerned has so much been accomplished during the past year. The Associate Editors carried out their work efficiently (and remained remarkably cheerful under the constant pressure for return of copy); three voluntary assistants, Mr. Kiyoshi G. Fukano, the late Mr. Henry E. Predmore, Jr., and Mr. Walter R. Crowe who took over Mr. Predmore's duties, performed invaluable services by assuming responsibility for many such details as the checking of membership lists, the distribution of proofs and of order blanks for reprints; Craft Press, the printer for Volumes 76, 77 and 78, handled materials rapidly, and what is even more important, agreed to perform work on two volumes simultaneously.

In many respects the past four volumes of the Transactions have not been well handled. Authors can complain with justice of cavalier treatment and other members can point to numerous defects in the several volumes. Some of these shortcomings no doubt reflect personal limitations of members of the Editorial Board, but many—perhaps most—could have been avoided if we had spent more time with each volume. Our policy has made every consideration subordinate to the major purpose of bringing the Transactions up to date. The sacrifice of the tender feelings of contributors and the processing of manuscripts and proofs at a rate that invited errors in the printed volume were both deliberate. Nevertheless, we regret deeply that they occurred.

Lest the preceding be misinterpreted as apologetic and the Board given undeserved credit for humility, let it be known that we feel collectively and individually that we have done rather well. Furthermore, we stand willing to defend our over-all procedure. We concede readily that complaints against our failure to return all edited manuscripts to authors for approval of changes and to distribute any page proof at all may have a certain legitimacy. On the other hand, we harbor only resentment for those who sent us articles in which the Society's specific instructions and all sound principles of good taste were violated indiscriminately and then decried our editorial efforts as infringements of author's prerogatives.

In our philosophy the obligations of the Editorial Board to the Society as a whole have outweighed all others. The members, whose support makes the publication of the TRANSACTIONS possible, deserve the very best volume that we can give them. They are entitled to protection from poorly arranged tabular material, cluttered-up illustrations, and textual matter burdened with clichés, irrelevancies, ambiguities, and solecisms. Authors should count it a privilege, not a right, to have papers appear in the TRANSACTIONS and should accordingly be happy to conform to the standards of that publication.

Conformity to accepted procedure and the good taste on which I have insisted so strongly during the past several years would require that in the last paragraph of this report I state how great has been the pleasure of serving as Editor, but I shall not so dissemble. I should dislike very much to close my editorial career with a misstatement of fact.

REPORTS OF SPECIAL COMMITTEES

COMMITTEE ON POLLUTION STUDY

EDWARD SCHNEBERGER

For the purpose of a report to the Society on the subject of pollution each member of the committee submitted papers to the chairman. In addition, the chairman solicited reports from Mr. Carl E. Schwob, Chief, Division of Water Pollution Control and Dr. C. M. Tarzwell, Senior Scientist, both of the U. S. Public Health Service. These reports were mimeographed and distributed to the members in attendance at the Winnipeg meeting. It is regretted that space does not permit the publication of these reports as prepared by the members in the TRANSACTIONS. The chairman expresses appreciation to each of the committee for their excellent contributions and presents herewith a brief summary of the papers.

Of great interest to the Society was the enactment of the Water Pollution Act, Public Law 845, in 1948, which culminated efforts for Federal legislation for the prevention and control of water pollution. Mr. Schwob outlines the program under this act. The report is best summarized by quoting certain paragraphs of Mr. Schwob's paper:

> Administration of Public Law 845 is divided between the Public Health Service of the Federal Security Agency and the Federal Works Agency. In summary the Act sets forth the declared policy of Congress: (1) to recognize, preserve, and protect the primary responsibilities and rights of the States in controlling water pollution; (2) to support and aid technical research; (3) to provide Federal technical services to State and interstate agencies, and to industries; and (4) to provide financial aid to States, interstate agencies, and municipalities in the formulation and execution of stream pollution abatement programs.
>
> The Act establishes a Water Pollution Control Advisory Board composed of five Federal representatives (Public Health Service, Departments of Army, Interior, and Agriculture, and the Federal Works Agency) and six non-Federal representatives to be appointed annually by the President.
>
> The financial provisions of the Act, six in number, are authorized for the fiscal years 1949-1953, inclusive. There is authorized to be appropriated to the Public Health Service, Federal Security Agency, for loans for remedial works $22,500,000 per year (Section 7); for grants to State and interstate agencies $1,000,000 per year (Section 8-a); for administration not to exceed $2,000,000 per year (Section 8-d). To the Federal Works Agency for grants to States, municipalities and interstate agencies for advanced plans of remedial works $1,000,000 per year (Section 8-c); for administration not to exceed $500,000 per year (Section 8-e); and for construction of a laboratory facility for Public Health Service use $800,000 per year (Section 8-b).

For field operations the country was divided into 14 drainage basin offices. However, because of limited finances several of the areas were combined to reduce the total to 10, all of which to be in operation by

September 1949. Some of the functions of the river basin office are as follows:

> Preparing a comprehensive river basin program for eliminating or reducing pollution of surface and underground waters.
>
> Representing the Public Health Service at all river basin meetings.
>
> Implementing recommendations made by a river basin water pollution control board and providing services to the Board.
>
> Preparing factual engineering reports on pollution situations.
>
> Maintaining accurate current records of pollution conditions in the basin.
>
> Providing liaison with the river basin board and local, state, and Federal agencies concerned with pollution.
>
> Assisting the States in their water pollution control programs, as in securing personnel, and services for conduct of investigations.
>
> Providing liaison to and working with the Environmental Health Center's field units in the conduct of studies.

The Environmental Health Center, long active in stream purification investigations and water and sewage treatment, is to be continued and expanded. The Cincinnati station is staffed and equipped to conduct such studies and investigations.

Dr. Tarzwell discussed the role of the aquatic biologist in a pollution abatement program. He points out that the purification of sewage and many other types of waste is dependent on living organisms and is therefore a biological process. The introduction of wastes into a stream produces a series of complex biological interactions and are dependable criteria of stream conditions. Since aquatic biologists are trained in limnology and stream ecology they are in position to lend considerable assistance to a water pollution control program.

Dr. Van Horn discusses the problem of industrial pollution. The principal methods used in treating industrial wastes are outlined and some of the major problems of treating industrial wastes are discussed. Dr. Van Horn states:

> The student of industrial waste treatment is confronted with a multitude of problems, many of which do not lend themselves readily to solution. Fundamentally, the problem is to remove solids, which may vary widely in character according to their origin in the diverse industrial processes. The methods employed for treatment will depend not only on the essential character of the waste water, but also on the degree of treatment necessary. That is to say, in some cases it is possible to effect partial purification — all that is necessary when the volume of the receiving water is sufficient to complete the process without adverse effects on itself.

The pollution problems along the west coast are discussed in reports by Robert M. Paul and Frank J. Kersnar, Sanitary Engineers, California Division of Fish and Game and Dr. D. B. Charlton, Oregon Division, Izaak Walton League, transmitted by Committee Member Needham. California's most important problem comes from fruit and vegetable canneries, closely followed by wineries. Sugar refineries are scattered throughout Central and Southern California producing wastes that are extremely offensive and difficult to handle. Reclamation of oils from the wastes of fish canneries has made partial waste treatment profitable to those concerns thus alleviating some of the problem. The effluents from oil refineries are not considered satisfactory even though oil separators are installed in most large refineries. Although the pollution problem in California is somewhat limited in scope it is expected to become bigger and broader as California industry grows and expands.

The leading problems in Oregon seemingly are concerned with domestic sewage, paper mills, and canneries. The problems are similar to those encountered elsewhere. The Izaak Walton League recommended legislation to provide a full-time director and a staff of qualified personnel for the state pollution control authority.

Mr. Kenneth A. Reid, whose activities toward adoption of Federal Water Pollution Control Legislation are well known by the Society, was asked to give an analysis of Public Law 845. Mr. Reid feels the bill was so "watered down" that it is of dubious value. Mr. Reid states:

> The Bill provides elaborate machinery for the U. S. Public Health Service to cope with water pollution, but then hamstrings its effectiveness by requiring state consent before the federal authority can act in any state. Obviously where federal authority is most needed is in those states that have been soldiering on the job and it is those very states that would be least likely to give their consent for the federal authority to come in.

Mr. Reid further criticizes the Bill's weakness in that it fails to stop the spread of pollution from new sources and the declaration of policy by Congress commits government to the job of discovery and developing industrial-waste treatment methods. He makes an interesting prediction as follows:

> We wish to make the prediction here that 5 years hence, we will be forced to admit that the present bill was a failure. But we will not only have lost 5 years—we will have gained another costly bureau which will continue indefinitely feeding at the public trough.

On the other hand, Mr. Reid feels there are some encouraging aspects of the law as it now stands. The provision for public hearings and the personnel of the Advisory Committee he feels are two items favorable toward pollution abatement. He is also pleased with the selection of Mr. Carl E. Schwob to administer the act. Mr. Reid closes with the statement:

> Summarizing, my recommendation would be to lend all possible support to Carl Schwob and the Advisory Committee, and then on the record of accomplishment or lack of accomplishment, go into congress with the needed amendments to make the Act what it was intended to be.. Unless it can show a record of real accomplishment in the next 2 years, I think Congress would find it difficult to refuse the amendments that the record indicates clearly are needed.

Mr. Marion Toole, covering the problem in the gulf states, reports on the basis of a questionnaire he submitted to Florida, Alabama, Mississippi, Louisiana, and Texas. In response to his question, "Do you have a worth-while pollution law in your state?" Florida and Mississippi answered "yes." Alabama reports their water improvement advisory commission did not receive regulatory powers. Texas replied they have a workable pollution law and while the penalty is not very severe they have been reasonably successful in enforcement of anti-pollution. Mr. Toole's other questions deal with the type of pollution encountered, damage done by pollution, and efforts being made to solve the various problems encountered. It can be stated that the gulf states are cognizant of their problems and are earnestly endeavoring to adopt corrective legislation and to work out treatment methods for the more difficult problems.

Dr. W. C. Senning of New York, reporting on conditions in the states along the Atlantic seaboard states, "It is apparent that the Eastern seaboard states are very conscious of their pollution problems and further that most of the states have taken initial steps necessary in the solution of these problems." Usually the responsibility is divided between various agencies, commonly, Health and Conservation; however, the trend is toward centralized authority and responsibility. Industrial wastes present greater problems than domestic sewage and have an important bearing on the shellfish industry. One Atlantic seaboard state reported having 58 shellfish areas closed because of pollution with one area reclaimed through proper sewage treatment. Most of the eastern states feel that although recent federal legislation will aid in pollution control, it is still the responsibility of the individual state. All of the states canvassed are in agreement that the two outstanding needs are (1) a well informed public aroused to the seriousness of the situation, and (2) adequate funds for the job ahead.

Dr. Harkness, reporting on Canada's pollution problem and its solution, provided a very comprehensive statement of the problems in the Dominion. The manufacture of pulp and paper is a major national industry and represents a special problem. Vegetable and fruit canneries, dairy plants, and sugar beet factories present problems that are seasonal and local. The disposal of sawdust and chip wastes may create a general local problem in almost any part of Canada. Domestic wastes particularly in periods of low water are a problem in many instances.

There is an active approach through research being carried on by Provincial Governments, the Federal Government, and industries to determine ways and means of economically recovering and utilizing waste substances, as well as to neutralize or otherwise treat such substances so that they are not detrimental to aquatic life.

In the administrative control of wastes the various government departments are supported by strict laws making pollution illegal. These laws are found in the Fisheries Act, the Migratory Birds Convention Act, the Lakes and Rivers Improvement Act, and the Public Health Act, respectively. In Canada, there is a fine balance between economical undertakings by industry or individual with respect to plant operation and purification of effluence. Industry, however, requires time, the amount dependent on the scope of the problem to bring about corrective measures.

Dr. Harkness makes two observations that clearly reflect the aggressive action Canada is taking toward the solution of this important problem of pollution control: (1) most industries undertaking new developments plan their work and waste disposal so that the effluence is clarified before gaining access to open waters, and (2) for the most part there is close cooperation between industry and administration in dealing with cases of pollution and in most instances warnings to the offending industry or individual is sufficient action toward bringing about remedial measures insofar as they can be accomplished.

The chairman is critical of the lack of interest and activity that fishery workers have displayed in the pollution abatement programs. He maintains that it is a vital and fundamental part of all fish and wildlife management programs and that unless we strive to protect and improve habitats, many of our other well developed plans are useless. Fishery workers must accept pollution control as part of their responsibility and they cannot expect others to carry the entire load in the effort to bring about clean waters. The public reaction is now favorable to abatement programs and it is necessary not only to keep this public interest up to the present level but also to show progressive developments in the abatement program. Therefore, the time is really ripe for the fishery worker to participate in the program.

COMMITTEE ON REVISION OF CONSTITUTION AND BY-LAWS

H. J. Deason

At the 1946 meeting a special committee consisting of Seth Gordon, James A. Rodd, and H. J. Deason was appointed to prepare a draft of a new Constitution and By-laws. At the 1947 meeting the committee presented an interim report and raised for debate a number of controversial questions so that it could proceed with drafting on the basis of a better knowledge of the desires of the membership. At the 1947 meeting the committee was enlarged by the appointment of Fred J. Foster (now deceased), W. A. Clemens, R. W. Eschmeyer, and Fred Thompson. The committee distributed an interim draft at the 1948 meeting in Atlantic City, requested comments by mail, and promised to have a final draft ready for vote at the 1949 meeting.

The Committee prepared a new draft which was mailed to all members on August 15, 1949, together with a letter requesting suggestions for amendment or revision prior to presentation of the Committee's final report and motion for adoption at this meeting.

The present drafts conform, with minor refinements, to the annotated drafts that were distributed at the 1948 meeting at Atlantic City, which were favorably received, and to three resolutions adopted at that meeting: (1) establishing a standing Membership Committee; (2) changing the name and composition of the Editorial Committee; and (3) establishing a Western Division of the Society. Since the annotated draft distributed at Atlantic City contained explanations concerning the source of basic material in the old Constitution and By-laws and concerning the new provisions inserted, such explanations are not included in the present drafts.

One basic feature of the new drafts is emphasized. The existing Constitution and By-laws are a single document and organization of material is confusing. Certain conflicting provisions and lack of clarity have caused confusion. The new drafts conform to approved parliamentary practice and consist of two separate instruments: (1) A Constitution, which is the basic framework within which the Society functions, and which may be amended only by a two-thirds majority vote of the members at any regular meeting (provided a quorum is present), provided that the proposed amendment has been recommended unanimously by the Executive Committee and circulated in writing to the membership at least 30 days prior to any meeting at which a vote on adoption is to be taken; (2) The By-laws, which spell out in detail the methods and procedures by which the Society functions, and which may be amended at any regular meeting by a two-thirds majority vote of the members at any regular meeting (provided a quorum is present).

For presenting the Constitution and By-laws for vote, the verbatim text will not be read. A brief statement concerning the contents of each article or section will be read. Two separate motions will be offered, one for adoption of the Constitution and one for adoption of the By-laws.

[Following the reading of a digest of the provisions of each Article of the Constitution and each section of the By-laws, the Society, by unanimous vote, adopted the documents in the following texts:]

CONSTITUTION OF THE AMERICAN FISHERIES SOCIETY

ARTICLE I

Name, Objectives and Purposes

1. The name of the organization shall be the American Fisheries Society, hereinafter referred to as the Society.

2. The objectives and purposes of the Society shall be:

(a) To promote the conservation, development and wise utilization of the fisheries, both recreational and commercial.

(b) To promote and advance the development and application of all branches of fishery science and practice, including aquatic biology, engineering, economics, fish culture, limnology, oceanography and technology.

(c) To gather and disseminate technical and other information on fishes, fishing, fisheries, and all phases of fishery science and practice.

(d) To hold meetings for the presentation, exchange, and discussion of information, findings and experience on all subjects and techniques related to fishes, fishing, fisheries, and all phases of fishery science and practice.

(e) By such other means as may be appropriate, to unite and encourage those interested in fishes, fishing, fisheries, and all other phases of fishery science and practice.

ARTICLE II

Membership and Election of Members

1. The membership of the Society shall be of the following classes:

(a) *Active Member:* Any person interested in the Society and in the furtherance of its purposes and objectives is eligible for election as an Active Member.

(b) *Life Member:* Any duly-elected active member, upon payment of the fee for life membership as specified in the By-laws, may retain his status as an active member throughout the remainder of his life and shall be exempt from any further payment of dues.

(c) *Sustaining Member:* Individuals, any sporting or fishing club, any socity, corporation or other organization is eligible for election as a sustaining member.

(d) *Library Member:* Any technical, public, private, or other library may become a library member.

(e) *Official Member:* Any Federal, State, Provincial, or Territorial department or agency of the United States of America, Government of Canada, United Mexican States, or any other American Republic is eligible for election as an official member.

(f) *Patron:* Any person, society, club, firm, corporation, or other organization is eligible to become a patron.

(g) *Honorary Member:* The President of the United States of America, the Governor-General of the Government of Canada, the President of the United Mexican States, the Governors of the States and Territories of the United States of America, the Lieutenant-Governors of the Provinces of Canada, the Secretary of the Interior of the United States of America, the Minister of Fisheries of Canada, and the Secretary of the Marine of Mexico shall be honorary members of the Society while serving in such official position. Any other person of note, by reason of his professional or other attainments, outstanding service to the Society, or his official position, shall be eligible for election as an honorary member.

2. Nominations for active membership, sustaining membership, library membership, official membership, and patron shall be submitted to the Secretary-Treasurer with the endorsement of at least one active member of the Society. Except as provided in paragraph 3, such nominations shall be presented to the members present at any regular or special meeting and shall be considered elected if they receive an affirmative vote of a majority of the members present at such meeting. Nominations for honorary membership shall be submitted with the endorsement of at least ten active members of the Society in good standing, and the unanimous vote of all members present at any regular or special meeting shall be required for election.

3. The Executive Committee, established pursuant to Article III, is authorized to consider and vote upon nominations for all classes of membership, except nominations for honorary membership, during the intervals between meetings. When so authorized by the Executive Committee, the President of the Society and the Secretary-Treasurer, acting jointly, may pass upon such nominations during the said intervals.

4. The names of elected members shall not be added to the membership rolls of the Society until they have paid such dues, fees or assessments for a period of at least one year as are enumerated in the By-laws adopted pursuant to Article V.

5. As used in this Constitution, and in the By-laws adopted pursuant to Article V, the term "member in good standing" means any active member, life member, sustaining member, or official member, whose dues are not more than one year in arrears; provided that a sustaining member or an official member shall be entitled to one vote.

ARTICLE III

Officers and Executive Committee

1. The officers of the Society shall be a President, a First Vice-President, a Second Vice-President, a Secretary-Treasurer, and a Librarian.

2. Only members in good standing who have been in attendance at one of the two regular meetings preceding their nomination or election shall be eligible for such nomination or election to one of the offices named in paragraph 1. Members who accept nomination and are elected to hold one of the offices of the Society, are bound to perform their duties to the best of their ability and to advance the purposes and objectives of the Society.

3. Officers shall be elected and serve for a period of one year, or until the next regular or annual meeting, and shall (with the exception of the Secretary-Treasurer and the Librarian) be ineligible for reelection to the same office for a period of one year after the expiration of their terms of office.

4. The officers named in paragraph 1, the President of the preceding year, the chairman of any regional division established pursuant to the provisions of Article VI, and the chairman of any standing committees established in accordance with the By-laws adopted in accordance with Article V, shall constitute the Executive Committee. The Executive Committee is authorized to decide the policies of the Society, and to transact such business of the Society as may be necessary between regular or annual meetings.

5. In the event of the cancellation of a regular or annual meeting, the officers enumerated in paragraph 1 of this Article and the members

of any standing or special committees established in accordance with the By-laws adopted in pursuance of Article V shall continue to serve until such time as a regular meeting can be scheduled at which new officers shall be elected and new committee members elected or appointed.

ARTICLE IV

Meetings and Voting

1. The Society shall meet once a year at a time and place to be decided upon by the membership at the preceding regular or annual meeting, or, in default of such decision by the membership, by the Executive Committee. Special meetings may be called by the President with the approval of the Executive Committee.

2. In the event of an emergency, the Executive Committee shall have the power to cancel a regular or annual meeting, or to change the place of an annual meeting; and in the event of such cancellation the Executive Committee shall have the power to schedule the next regular meeting.

3. A quorum at any meeting for the transaction of official business shall consist of at least twenty-five active members in good standing.

4. Decisions at meetings, including election of members, shall be by a majority of those present at any meeting; *except that* for election of officers and members of committees, and for a motion for amendment of By-laws adopted pursuant to Article V, a two-thirds majority shall be required; and *excepted further,* a unanimous vote shall be required for the election of honorary members.

ARTICLE V

Authorization for the Adoption of By-laws

1. The Society is authorized to adopt and to amend subsequently as may be required, in accordance with the provisions of paragraph 4 of Article IV, such By-laws as may be necessary for the conduct of the business of the Society.

2. By-laws adopted pursuant to the provisions of this Article must include, but shall not be limited to, the following:

(a) Set forth the amount of annual dues and special fees or assessments for the various classes of membership of the Society, and deal with other matters pertaining to the finances of the Society.

(b) Prescribe the duties of officers of the Society.

(c) Provide for the establishment of and specify the terms of reference or duties of such standing committees, other than the Executive Committee established in accordance with paragraph 4 of Article III, and such sessional committees as may be necessary for the conduct of the business of the Society and the furtherance of its purposes and objectives. For the purposes of this subparagraph, (1) a standing committee is defined as one which is established permanently in the By-laws as a part of the basic organization of the Society; and (2) a sessional committee is defined as one constituted for the purpose of undertaking specific tasks at or in preparation for a regular or special meeting of the Society and is discharged upon submission of its report or completion of its business.

(d) Notwithstanding the provisions of subparagraph (c) of this paragraph, the President with the consent of the Executive Committee may appoint, or the Society, by adoption of an appropriate resolution, may authorize the President to appoint *ad hoc* committees to undertake special assignments; any such authorization or appointments shall not require amendment of the By-laws, and such committees shall automatically be abolished on completion of their assignments or on the date of the next regular meeting, whichever occurs first.

(e) Provide authorization for such official publications of the Society as may be necessary in the furtherance of its purposes and objectives.

(f) Provide for the establishment and maintenance of any regional divisions of the Society established pursuant to the provisions of Article VI.

ARTICLE VI

REGIONAL DIVISIONS

1. A regional division of the Society may be established by the favorable action of the Society, pursuant to paragraph 4 of Article IV, upon a petition presented to it at any regular meeting by not less than twenty-five members of the Society in good standing resident in a particular geographic region.

2. Such regional division or divisions shall be organized in accordance with pertinent provisions of the By-laws adopted pursuant to Article V.

3. Each such regional division may adopt and amend from time to time its own By-laws, which shall conform to the provisions of this Constitution and By-laws of the Society adopted pursuant to Article V. The By-laws of regional divisions, after adoption and each amendment, shall be reviewed by the Executive Committee of the Society to insure conformance with the Constitution and By-laws of the Society. No By-laws of regional divisions or amendments thereof shall be considered effective until such review by the Executive Committee of the Society has been completed and the chairman of the regional division has been notified in writing by the Secretary-Treasurer of the Society that such by-laws or amendments thereof are in conformity with the Constitution and By-laws of the Society.

4. Each regional division shall elect its officers, which shall consist of a chairman, vice-chairman and secretary. The chairman of any regional division shall be a member of the Executive Committee of the Society, and in his absence or inability to attend meetings of the Executive Committee the vice-chairman of that regional division may act in his stead. The secretary of any regional division of the Society shall

serve as an assistant to the Secretary-Treasurer of the Society and shall carry out his duties in accordance with such procedures as may be determined from time to time by the Secretary-Treasurer of the Society.

5. All members of the Society who reside within a designated region in which a regional division of the Society may be established shall, upon election to membership and payment of dues prescribed in the By-laws, be considered a member both of such regional division and of the Society as a whole. Qualifications for membership in regional divisions shall conform to qualifications for membership in the Society. Regional divisions may elect active and life members only. The other classes of membership set forth in Article IV shall be elected only by the Society.

6. The regional divisions may, with the approval of the Executive Committee of the Society, levy such special fees, in addition to the dues of regular members of the Society, as may be necessary to meet any expenses of the regional divisions which are not properly chargeable to the regular funds of the Society. All regular Society dues shall be paid only to the Secretary-Treasurer of the Society. Any special fees collected by the regional division shall be disbursed by the secretary of the regional division in accordance with the By-laws of such regional division and the authorization of its officers and members.

7. The Executive Committee may allot to any regional division, from time to time, such sums from the treasury of the Society as may be necessary to further through the regional division the purposes and objectives of the Society. Such allotted funds shall be disbursed by the secretary of the regional division in accordance with its By-laws and the decisions of its officers and membership.

ARTICLE VII

Amendment of Constitution

1. This Constitution, after adoption in accordance with the provisions of the existing Constitution and By-laws, shall supersede such previously adopted Constitution.

2. This Constitution may be amended upon unanimous recommendation of the Executive Committee which shall be circulated in writing to the membership at least 30 days prior to any regular meeting at which a vote is to be taken, and upon approval by a two-thirds majority of the members present at such regular meeting, provided a quorum is present.

3. A petition for amendment of this Constitution signed by not less than 50 members in good standing; irrespective of any action relative thereto taken by the Executive Committee in pursuance of paragraph 2 of this Article, shall be circulated to the membership by the Secretary-

Treasurer at least 30 days prior to a regular meeting, and such amendment shall become effective upon approval by a two-thirds majority of the members present at such regular meeting, provided a quorum is present.

BY-LAWS OF THE AMERICAN FISHERIES SOCIETY

Section 1.—Duties of the President

The President is responsible for the business and organization of the Society, shall make such appointments as are authorized in the By-laws, and shall exercise such other functions and responsibilities as may be determined from time to time by action of the Society or the Executive Committee. He shall preside at all meetings of the Society, and at all meetings of the Executive Committee, of which he is chairman.

Section 2.—Duties of the Vice-Presidents

The First Vice-President shall assume the duties of the President during his absence or in case of his inability to act. The Second Vice-President shall assume the duties of the President during the absence of the President or the First Vice-President or in case of their inability to act. The First Vice-President is chairman of the Membership Committee provided for in Section 16, and in case of his absence or inability to act such chairmanship shall be assumed by the Second Vice-President. Upon designation by the President, the First Vice-President or the Second Vice-President shall preside at any necessary simultaneous sectional sessions at regular meetings.

Section 3.—Duties of the Secretary-Treasurer

The Secretary-Treasurer, in his capacity as Secretary, shall be responsible for maintaining the official records of the Society, shall conduct its official correspondence, promote its membership, and shall make arrangements for regular and special meetings of the Society, and for meetings of the Executive Committee. He shall serve as parliamentary advisor to the President and chairman of committees to insure that the business of the Society is conducted in accordance with the provisions of the Constitution and By-laws.

The Secretary-Treasurer, in his capacity as Treasurer, shall receive and collect all dues, fees, accounts receivable, and other income of the Society, shall have the custody of its funds, and shall pay all accounts payable and other claims which have been duly authorized and approved. He shall furnish a bond in the sum of $7,500, on surety, to be approved by the Executive Committee, the premium for such bond to be paid by the Society. The Secretary-Treasurer shall present an annual report to the Society.

Section 4.—Duties of the Librarian

The Librarian shall have the custody of the library of the Society, including its archives and printed publications, and shall have charge of the sale of extra copies of its publications. He shall transmit promptly to the Secretary-Treasurer monies received from such sales.

Section 5.—Expenses of Officers

No elected officer or committee member of the Society shall receive any salary or other compensation for his services. Clerical and other necessary expenses of elected officers and committee members may be defrayed by the Society provided that it has, through action at a regular meeting, or by vote of the Executive Committee in the event of an emergency during the interval between regular meetings, authorized such disbursements in advance.

Section 6.—Official Publications

The minutes and proceedings of all regular and special meetings of the Society and of any regional division established pursuant to Article VI of the Constitution, together with reports of officers and committees at such meetings, technical papers presented by the members and selected by the Editorial Committee for publication, and the official membership list of the Society shall be published in an annual volume which shall be numbered in series with the preceding volumes and shall be entitled: TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY. Each member of the Society in good standing shall receive one copy of the annual volume of TRANSACTIONS. Honorary members shall be sent a copy of each volume of the TRANSACTIONS only on receipt of a written request therefor.

Section 7.—Presentation and Publications of Manuscripts

Only members in good standing may present papers, either by reading or by title, at annual meetings of the Society or at meetings of regional divisions of the Society, and submit them for publication by the Society; *except* that outstanding non-members invited by the President of the Society, the Secretary-Treasurer with the advice of the President, or the chairman of any regional division, to present papers at any meeting shall be exempt from this requirement. No member may have listed on the program of any meeting of the Society or any regional division thereof, or present, or have published in any one volume of the TRANSACTIONS, more than two papers; and for purposes of this section joint authorship shall be considered in the same status as sole authorships.

Section 8.—Dues of Members The dues of the various classes of members, payable to the Secretary-Treasurer of the Society, shall be as follows:

(a) Active member, $4.50 per annum.

(b) Life member, $75; payable, if desired, in two consecutive annual installments of $37.50 each.

(c) Library member, $4 per annum.

(d) Sustaining member, $10 per annum.

(e) Official member, $40 per annum.

(f) Patron, a single contribution of $250 or more.

(g) Honorary member, no dues.

All dues, fees, or other monies due the Society shall be paid in currency of the United States of America, or the equivalent in foreign currency at current rates of exchange in the United States of America.

Section 9.—Loss of Membership Any member who fails to pay his dues for a period of more than one year shall be given written notice by the Secretary-Treasurer that his name will be removed from the membership list unless back dues are paid in full within 60 days from the date of such notice. Any member who has forfeited his membership may not be reelected as a member for a period of one year from the date of forfeiture of his membership unless he has paid all back dues and has paid dues for one additional year in advance.

Section 10.—Committee on International Relations The Committee on International Relations is a standing committee responsible for keeping the Society informed as to the work of foreign technical agencies, international organizations, meetings, conferences, negotiations, exchange of persons and information, and related international matters of interest to the Society, and shall recommend such action or participation by the Society as may be appropriate in the furtherance of the Society's purposes and objectives. It shall consider problems of legislation and implementation of international agreements relating to the interests, purposes and objectives of the Society. The Committee shall consist of seven members in good standing, who shall be named by the nominating committee and elected by the Society. The Committee shall report to the Society annually concerning its work.

Section 11.—Committee on National-State Relations The Committee on National-State Relations is a standing committee which shall act as a coordinating and advisory board for the consideration of interstate and National-State fishery problems and programs in the United States of America. It shall also consider problems of administration of fishery resources, and Federal and State legislation and the implementation thereof in the fields of fishery conservation and management. The Committee shall consist of five members in good standing, at least one and no more than two of which shall be an officer or officers of the United States Government, who shall be named by the nominating committee and elected by the membership. The Committee shall report annually to the Society concerning its work, which report shall include such recommendations for action by the Society as are considered appropriate.

Section 12.—Editorial Committee

The Editorial Committee is a standing committee responsible for the editing and publication of the proceedings of meetings, including technical papers and other manuscripts, and for their publication in the name of the Society. The Committee shall consist of eight members in good standing of proven technical and editorial abilities, each of whom shall serve for a term of four years. Each President, immediately upon his election, shall appoint two new members of the Committee and shall designate the chairman for the ensuing year; *provided that,* the member designated to serve as chairman must have served as a member of the committee for at least one year. The chairman of the Committee shall be known as the "Editor" and the other members shall be called "Associate Editors." The Editor shall assign duties to the Associate Editors, and may solicit assistance, from time to time, for temporary periods from other members of the Society. The Committee is authorized to establish and issue such standards and instructions to the membership as may facilitate its work. The Committee shall report to the Society annually concerning its work.

Section 13.—Committee on Hydrobiology and Fish Culture

The Committee on Hydrobiology and Fish Culture is a standing committee which shall maintain a continuous survey and appraisal of research and applied work in the fields of aquatic biology, physiology, limnology, and oceanography as related to fishery science, fish culture, and fishery management. It shall develop and encourage the standardization and improvement of techniques, procedures, nomenclature, and measurements; and shall consider problems of pollution control. The Committee shall be composed of seven members in good standing who are recognized specialists in various phases of fishery science and practice, and who shall be named by the nominating committee and elected by the membership. The Committee shall report annually to the Society concerning its work, placing emphasis on developments during the past year.

Section 14.—Committee on Commercial Fisheries

The Committee on Commercial Fisheries is a standing committee responsible for promoting and improving fishery techniques and the utilization of fishery resources for food and by-products, for the development and recommendation of standards of quality and sanitation, for the development and recommendation of standardized procedures for the collection and analysis of fishery statistics, and for related activities. The Committee shall be composed of seven members in good standing who are recognized specialists or authorities in fishery economics, technology, or the fishery industries, and who shall be named by the nominating committee and elected by the membership. The Committee shall report annually to the Society concerning its work, placing emphasis on developments during the past year.

Section 15.—Committee on Names of Fishes

The Committee on Names of Fishes is a standing committee responsible for the establishment and maintenance of a check list of common and scientific names of fishes, with the objective of achieving uniformity and avoiding confusion in nomenclature. The Librarian shall be custodian of the master check list. The Committee, in the furtherance of its duties, shall coordinate its activities with those of other societies and organizations throughout the world. The Committee shall be composed of seven members named by the nominating committee and elected by the membership, such members to be outstanding specialists in the fields of systematic ichthyology and fishery biology. The Committee shall report to the Society annually concerning its work.

Section 16.—Membership Committee

The Membership Committee is a standing committee responsible for maintaining and increasing the membership of the Society. The Committee shall take such measures as it deems appropriate and effective to stimulate interest in the Society and to further its purposes and objectives by interesting qualified persons in membership. The Committee shall consist of the First Vice-President, who shall be chairman, and nine other members in good standing who shall be appointed by the President within 30 days after his election. The Secretary-Treasurer shall be an *ex-officio* member. The Committee shall report to the Society annually concerning its work.

Section 17.—Program Committee

The Program Committee is a standing committee responsible for arrangement of the program at the regular meetings, consisting of technical sessions for the reading and discussion of original papers, symposia on important topics, and exhibits of interest to the Society. It is the duty of the Committee to insure that the programs at the regular meetings are of high quality and achieve balance among the various fields of interest and activity of the Society. The Committee may recommend to the President the issuance of invitations to outstanding non-members to present papers or addresses. The Committee shall consist of five members in good standing appointed by the President within 30 days after his election, who shall serve until the close of the next annual meeting.

Section 18.—Sessional Committees

The President is authorized to appoint, from the members of the Society in good standing, prior to, or at the beginning of each regular meeting, such sessional committees as may be necessary for the conduct of the business of the Society and other authorized activities in conjunction therewith; including the following:

(a) Nominating Committee of five, which shall name a list of officers and members of Committees that are subject to election by the Society, which shall be presented to the members for action at a regular meeting. It is the duty of the Committee to insure that all persons named shall conform to the qualifications for the various offices and committee memberships set forth in the Constitution and By-laws. The right of any member to nominate a candidate for any office or committee membership from the floor during a regular meeting, or to second such nomination, is expressly reserved.

(b) Resolutions Committee of five, which shall draft and recommend to the Society for consideration and vote at a regular meeting such resolutions, including amendments of the By-laws, as may be considered prudent and necessary for the furtherance of the purposes and objectives of the Society and for the conduct of its business.

(c) Auditing Committee of three, which shall examine the accounts of the treasurer and report its findings to the Society, and shall consider the annual budget of the Society prepared by the Secretary-Treasurer with the advice of the Executive Committee, and make recommendations concerning it for the action of the membership.

(d) Time and Place Committee of five, which shall consider and recommend to the membership for action, the time and place for the next regular meeting.

(e) Publicity Committee of three members, which shall draft, approve, and disseminate appropriate press notices and reports concerning the meetings of the Society and the proceedings thereat as may be appropriate and in furtherance of the purposes and objectives of the Society.

Section 19.—Order of Business

The order of business at regular meetings of the Society shall include, but shall not necessarily be limited to, the following:

1. Call to order by the President.
2. Address of the President on a timely subject of his choice.
3. Roll call of members (or determination that a quorum is present).
4. Action on nominations for membership.
5. Introduction of noteworthy guests and visitors.
6. Appointment of sessional committees by the President:
    a. Nominating Committee of five.
    b. Resolutions Committee of five.
    c. Auditing Committee of three.
    d. Time and Place Committee of five.
    e. Publicity Committee of three.
7. Report of the Secretary-Treasurer.
8. Report of the Librarian.
9. Report of the chairmen of regional divisions.
10. Reports of Standing Committees.
11. Reports of *ad hoc* committees.
12. Program of papers, symposia, and discussions.
13. Report of the Time and Place Committee.
14. Report of the Auditing Committee.
15. Report of the Resolutions Committee.
16. Report of the Nominating Committee.
17. Election of officers and members of such standing committees as are subject to election by the membership.
18. Installation of newly-elected officers.
19. Other business.
20. Adjournment.

Section 20.—Western Division

(a) In accordance with the provisions of Article VI of the Constitution, there is hereby established a Western Division of the AMERICAN FISHERIES SOCIETY, which shall be constituted of members in good standing from the eleven western States and the Territories of Alaska and Hawaii of the United States of America; and from the Provinces of Alberta, Saskatchewan, and British Columbia of the Dominion of Canada.

(b) The Chairman of the Western Division shall submit a report to the Society at each regular meeting.

(c) The Secretary of the Western Division shall submit a report to the Secretary-Treasurer of the Society at each regular meeting.

REPORT OF THE CHAIRMAN OF THE WESTERN DIVISION

Paul R. Needham

At the St. Paul, Minnesota, meeting in 1946, the writer made a motion at the concluding business sessions that a committee be appointed to study the matter of setting up a western Division of the parent Society. This motion was seconded by Dr. H. J. Deason and passed unanimously. At the Denver meeting in September, 1947, a committee of six was appointed to establish a Western branch of the American Fisheries Society. The committee appointed consisted of Fred A. Thompson (Chairman), A. C. Taft, W. L. Reavley, Dr. J. S. Hart, M. J. Madsen, and myself. By mutual agreement among members of this committee, plans were made to meet with the Western Division, Western Association of Game and Fish Commissioners, at their Salt Lake City meeting held in June, 1948. Consent was arranged for such a joint meeting through Mr. Ross Leonard who at that time was President of the Western Association. This meeting lacked the sanctity of legality for the parent body had not at that time changed its constitution authorizing the establishment of regional divisions. However, the necessary changes in the Constitution were completed and adopted at the Atlantic City meeting held in September, 1948. Thus the meeting held in Seattle in June, 1949, was the first official one to be held under Article VI of the Constitution of the parent body that authorizes the establishment of regional divisions. We much appreciate the continued opportunity of meeting with the Western Association of Game and Fish Commissioners and believe that the union will prove a happy and profitable one and one which will contribute materially to our understanding of western fish management and stocking problems.

At the Salt Lake meeting held with the Western Association in 1948, the nominating committee recommended the following slate of officers: Dr. John L. Hart, Vice-Chairman, Mr. Fred A. Thompson, Secretary-Treasurer, and myself as Chairman. Election was unanimous and the Western Division was launched and under way.

For the Seattle meeting last June, again held in conjunction with the Western Association of Fish and Game Commissioners, I appointed the following committees: Program committee: Clarence Pautzke, *Chairman,* Don McKernan, Dr. Richard Crocker, Mr. Fred A. Thompson, Ray Hess, and Dr. Ferris Neave. To Clarence Pautzke and the other members of his committee, we owe a large vote of thanks for their efforts in arranging the program for that meeting. Last but not least, it was necessary that we have a Constitution and By-laws drawn up for the Western Division and to meet this need I appointed the following committee to prepare these items for presentation at the Seattle meeting: Mr. F. R. Butler, *Chairman,* A. C. Taft, A. W. Yoder, A. V. Green, and J. C. Simpson. This group prepared a tentative Constitution and By-laws which were read and discussed at the business sessions. Since a few changes seemed desirable, this Committee is continuing its work and will present a re-drafted version for consideration of our western members at the Winnipeg meeting.

New officers elected for the Western Division at the Seattle meeting were: Dr. John L. Hart of Canada, Chairman, and Mr. James Simpson, Idaho, Vice-Chairman; Mr. Fred A. Thompson of New Mexico was re-elected Secretary-Treasurer. As the retiring Chairman, I would like to thank both our officers and members for their splendid cooperation and help in getting the Western Division under way. Two individuals need to be mentioned specifically here. These are Seth Gordon and Fred Thompson.

I would like to add a little to that, that Mr. Seth Gordon was a tremendous help in our first recognized meeting of the Western Division in Seattle. He, like a fond father watching the children keep out of trouble, did not bother them until they came screaming to him for help. We had to rely on Mr. Gordon a few times to straighten out some of our problems. Mr. Gordon luckily happened to be in California while the Western Division was getting under way and we owe him much for the sound advice and good help he gave us from time to time. Fred Thompson had worked hard on Western Division matters and he likewise deserves much credit for the successful launching of the Western Division.

At the Salt Lake City meeting, we had an attendance of some 43 fisheries workers. In Seattle a year later attendance of fisheries workers jumped to well over 100 and I think it may be said that we are on our way now toward setting up an efficient, smoothly-operating organization and one that will be well-fitted to serve members of the AMERICAN FISHERIES SOCIETY living in the Western United States and Canada. Our problems in the west are different from eastern and midwestern problems, and distance to national meetings precludes the free exchange of ideas that would be desirable through local meetings such as this one. I am confident that the Western Division of the AMERICAN FISHERIES SOCIETY can do much to forward progressive fisheries management programs and policies in western areas and in so doing greatly strengthen the effectiveness of the Society as a whole on a national basis.

REPORTS OF SESSIONAL COMMITTEES

COMMITTEE ON TIME AND PLACE

George W. Davis

The Committee on Time and Place met with the corresponding committee of the International Association of Game, Fish, and Conservation Commissioners. Acceptance was recommended of the invitation issued by the State of Tennessee. Later, at a meeting of the executive committees of the two societies, it was agreed that the 1950 meeting of the American Fisheries Society shall be held in Memphis, Tennessee, September 11 and 12, to be followed by a field trip September 13, and by the meeting of the International Association of Game, Fish, and Conservation Commissioners September 14 and 15.

AUDITING COMMITTEE

Lloyd L. Smith, Jr.

The Auditing Committee has examined the accounts of the American Fisheries Society for the period September 1, 1948, to August 31, 1949, and finds them to be in good condition, and consistent with good bookkeeping practices.

The committee wishes to commend the Treasurer and his assistants for their exemplary handling of the Society's records.

RESOLUTIONS COMMITTEE

C. R. Gutermuth

1. *Hoover Commission Report*

Whereas, Some of the Task Force reports of the Hoover Commission were in decided disagreement with the majority report of the Commission; and

Whereas, There is a widespread belief that a new and distinct Department of Natural Resources with cabinet status is urgently needed to insure the best utilization of all natural resources in the broad public interest; now therefore

Be It Resolved, That in furtherance of better coordination and efficiency in the administration of all federal activities concerned with the conservation and management of natural resources, the American Fisheries Society urges the adoption by Congress of the recommendations of the *Report on Natural Resources, Appendix L,* published in January 1949, by the Task Force of the Commission on Organization of the Executive Branch of the Government providing for a unified Federal Department of Natural Resources, except that the Society opposes that portion of the report which recommends separation of fisheries administration from wildlife administration.

2. *Great Lake Fisheries Treaty*

Whereas, The fisheries of the Great Lakes are an important source of fresh-water fish for the markets of the United States and Canada; and

Whereas, The fisheries have declined substantially in recent years, with equivalent reduction in employment, a decided loss of income to the communities bordering the Great Lakes, and a significant loss of food to the people of both countries; and

Whereas, The Treaty enacted in April, 1946, at the Convention for the Development, Protection and Conservation of the Great Lakes Fisheries, still has not been ratified by the Senate of the United States; now therefore

Be It Resolved, That the American Fisheries Society hereby reaffirms the imperative need for control of the fisheries by international agreement and urges the prompt ratification of the Treaty by the Senate.

3. *Federal Aid to State Fisheries*

Whereas, The American Fisheries Society has upon several occasions, in meeting assembled, urged the enactment of congressional legislation to provide federal aid to state fisheries comparable to the Federal Aid in Wildlife Restoration (Pittman-Robertson) Act, and whereas, the Dingell Bill, H.R. 1746, has been passed by the lower House of Congress, and by the Senate with slight clarifying amendments; now therefore

Be It Resolved, That the Secretary write to President Harry S. Truman and urge him, in the name of the Society, to give his approval to this legislation that is designed to improve fishing for increased citizen recreation and more abundant food for human consumption.

4. *Appreciation to John D. Dingell*

Whereas, The Hon. John D. Dingell (Michigan) worked tirelessly to secure passage of the Federal Aid to State Fisheries Bill, H.R 1746; and

WHEREAS, The enactment of this legislation constitutes one of the most important advancements in history for the development of sport fisheries throughout the United States; now therefore

BE IT RESOLVED, That the American Fisheries Society expresses sincere appreciation to Congressman Dingell for his singular contribution to the improvement of fisheries management in the public interest; and

BE IT FURTHER RESOLVED, That the Society urges President Truman to sign this bill so that the fishery resources of the nation may be developed in a manner comparable to that provided under the Federal Aid to Wildlife Restoration (Pittman-Robertson) Act passed by the Congress in 1938.

5. *Administration of Federal Aid to Fisheries*

WHEREAS, Pending congressional legislation would place the administration of the provisions of the Dingell bill under the U. S. Fish and Wildlife Service; and

WHEREAS, The mechanics of this bill are similar to that of the present Pittman-Robertson Act, now therefore

BE IT RESOLVED, That the Fish and Wildlife Service consider the advisability of administering both activities under one federal-aid head with a Branch of Fisheries and one of Game rather than setting up a separate division for the administration of fisheries federal-aid.

6. *Stream Pollution Abatement*

WHEREAS, Preventable delays in the abatement of stream pollution are resulting from the failure of private industry to construct the necessary costly and non-productive treatment plants for the elimination or purification of industrial wastes; and

WHEREAS, The Congress has recognized the benefits to public health and welfare from the abatement of stream pollution by enacting the Water Pollution Control Act of 1948; and

WHEREAS, Several bills are pending in both the House and Senate which would encourage the prevention of water pollution by tending to induce firms and corporations to construct industrial waste treatment works; now therefore

BE IT RESOLVED, That the American Fisheries Society urges the Congress to enact legislation that would assist and encourage private industry to construct approved treatment plants by allowing the amounts paid for such works to be amortized at an accelerated rate through a reduction in computing net income for tax purposes.

7. *Fish and Wildlife on Military Reservations*

WHEREAS, The principal responsibility for management, regulation, and use of fish and wildlife resources always has been recognized as resting with the states, and

Whereas, Due to the war emergency, the necessity for restriction of the public use of certain areas for military purposes was cheerfully recognized by the public; and

Whereas, Since the war emergency has terminated and need for such restrictions has passed, but nevertheless the Department of the Army has continued to maintain the same and to exclude the public from the benefits of the fish and wildlife resources of such areas, and to limit the use thereof to military personnel and their friends and associates; now therefore

Be It Resolved, That the American Fisheries Society objects to such restrictions and urges that the control of the fish and wildlife resources of such areas be restored to the states for public use and benefit, and that Congress enact appropriate legislation to that end if necessary.

8. *Mining City Dam Project*

Whereas, The proposed Mining City Dam Project of the Corps of Engineers would cause serious damage by flooding both the Echo River and new discovery sections of Mammoth Cave National Park; and

Whereas, The contemplated dam in Green River, Kentucky, would destroy precious geological, anthropological, and biological resources, including the peculiar blind fishes, all of which should be preserved in the public interest; and

Whereas, Mammoth Cave National Park, containing one of the most extraordinary systems of limestone caves in the world, was purchased by Kentuckians at a cost of millions of dollars and represents an extremely valuable gift to the people of the nation; now therefore

Be It Resolved, That the American Fisheries Society adds its protest to that of the Secretary of the Interior and voices strenuous objection to the Mining City Dam Project or to any modification of the overall flood control plan for this area that would impair present values of Mammoth Cave National Park.

9. *Valley Authorities*

Whereas, None of the legislative proposals conceived to date for the establishment of so-called Valley Authorities or Administrations have recognized the imperative need for complete watershed management; and

Whereas, Full consideration has not been given to the value of water as a vital public resource; and

Whereas, Every Valley Authority or Administration proposal advocated to date has disregarded certain fundamentals basic in the inherent concept of state rights; now therefore

Be It Resolved, That the American Fisheries Society opposes the enactment of any Valley Authority or Administration legislation that does not mandate full use of approved practices and techniques for the prudent management of soil, water, fishery, and wildlife resources and that does not assure maximum utilization of these valuable resources to the citizenry in the entire watershed of the river basin involved; and

Be It Further Resolved, That if and when such Valley Authority or Administration legislation is enacted, the Congress is urged to include provisions that will maintain the rights of the various states concerned for complete and unrestricted control over the fish and game resources within such established authorities.

10. Development of the Territory of Alaska

Whereas, The Bureau of Reclamation of the Department of the Interior definitely is endeavouring to have the reclamation laws extended to include the Territory of Alaska; and

Whereas, When testifying in favor of H.R. 940 recently, which would authorize the construction of the Eklutna Hydroelectric Generating Plant and transmission facilities near Anchorage, the Department of the Interior stated that "The reclamation laws should be extended to embrace the Territory of Alaska, and separate legislation to accomplish that purpose is under consideration"; now therefore

Be It Resolved, That the American Fisheries Society opposes the planned Eklutna Project, the expansion of the reclamation laws to include Alaska, and the contemplated water-resources devolpments in the Territory until it is proved that they are not premature and unwarranted.

11. Income for U. S. Forest Service

Whereas, The U. S. Forest Service administers nearly 200 million acres of public land containing 90,000 miles of fishing streams and rivers, and 1½ million acres of lakes and ponds; and

Whereas, These waters are open to the public for recreational fishing under state fishing regulations; and

Whereas, The annual appropriations for the Forest Service have been inadequate to maintain the same 5,000 public recreational areas, including camp grounds, picnic areas, and other facilities used by fishermen and other recreational users; and

Whereas, Appropriations for this federal agency have been inadequate to advance needed work in habitat and cooperative fisheries management on the national forests; now therefore

Be It Resolved, That the American Fisheries Society urges the passage of the pending bills in Congress, H.R. 2419 and S. 2409, which would allocate 10 percent of the income received from each national forest during each fiscal year for the development, maintenance, and operation of national forest recreational resources and areas, including wildlife resources.

12. High Dams

WHEREAS, The American Fisheries Society repeatedly has urged that full consideration be given to all natural resources in the planning and development of high dams constructed for flood control power and irrigation purposes; and

WHEREAS, Serious exploitation and destruction of precious resources have resulted from the erection of many high dams in which true public values were not given full consideration; and

WHEREAS, The construction agencies have been permitted to proceed with development projects without consideration of biological field reports; now therefore

BE IT RESOLVED, That the Society staunchly opposes the future authorization or construction of any high dams, in the United States and Canada, regardless of their stated purpose, until such time as opportunity has been afforded to appraise the effects of such projects and the reports thereon have been made an integral part of the factual data upon which the final decision is reached, so that all values from the standpoint of the broad public interest may be given full consideration; and

BE IT FURTHER RESOLVED, That the Society objects to the construction of any high dam unless and until it can be shown that the new values to be created, definitely exceed the existing public values displaced; and

BE IT FURTHER RESOLVED, That since the International Joint Commission has performed outstanding service in effecting sound utilization of border water resources, the Society urges that consideration be given to the establishment of similar impartial boards of review in respect to water-resources use on a national basis.

13. Quetico-Superior Memorial Forest

WHEREAS, There exists in the Rainy Lake watershed located in Ontario and Minnesota, an incomparable area of lakes and rivers and forests known as the Quetico-Superior Region; and

WHEREAS, It has been proposed that an International Peace Memorial Forest be established in this area to safeguard the unique wilderness values of the interior country, to perpetuate its fish, wildlife, and other recreational resources for the future benefit of both nations; and

WHEREAS, This forest is to be dedicated in the name of peace and international good will to the veterans of both countries who fought in World Wars I and II; now therefore

BE IT RESOLVED, That the American Fisheries Society endorses this great international project, urging its speedy completion by treaty between the Dominion of Canada and the United States of America.

14. International Participation and Co-ordination

Whereas, The American Fisheries Society is of international nature and constitutionally provides for acceptance of members and participation of these members in all functions of the Society regardless of governmental or territorial boundaries; and

Whereas, The present membership is made up largely of members from the United States and Canada; now therefore

Be It Resolved, That the Society extends a cordial welcome to fishery workers in the Latin American countries to become members and participate in the exchange of ideas through sending official representation to the meetings and the presentation of papers for publication in the Transactions; and

Be It Further Resolved, That the Secretary be instructed to send a copy of this resolution to the proper offices of each Latin American country along with appropriate literature explaining the functions of the Society.

15. Representation at Society Meetings

Whereas, The American Fisheries Society is the oldest recognized international fisheries organization in the western hemisphere dealing with all fishery problems of local, national and international scope; and

Whereas, It is of vital importance that all workers in this field be familiar with the activities of the Society and avail themselves of the benefits of the knowledge, recent findings, and current trends discussed in the annual meetings; and

Whereas, The strength of the Society is necessary to present a strong front on major problems of state, provincial, national and international scope that are of vital interest to fishery resources; now therefore

Be It Resolved, That the Society urges the executive and conservation authorities and other interested agencies of the several states and provinces, and especially those who may control conservation operations but who are not active in the fisheries field, to send representatives from their departments to attend and participate in the annual meetings of the American Fisheries Society.

16. Appreciation of Hospitality

Whereas, The Society has been extended unexcelled privileges and been entertained graciously at its 79th Annual Meeting in Winnipeg, Manitoba, Canada; and

Whereas, The members and guests have enjoyed extraordinary courtesies; now therefore

Be It Resolved, That the American Fisheries Society express its sincere appreciation and profound gratitude to the Dominion of Canada, the Province of Manitoba, the Department of Mines and Natural Resources, its Minister, The Honourable J. S. McDiarmid, Mr. D. M. Stephens, the Deputy Minister, and Director of Game and Fisheries, G. W. Malaher, and G. E. Butler, the other members of the staff, and the ladies' committee who made this meeting a tremendous success. Special acknowledgment likewise is extended to Delta Waterfowl Research Station, Ducks, Unlimited (Canada), the city and people of Winnipeg for their gracious hospitality.

COMMITTEE ON NOMINATIONS

Joe Hogan

The Committee on Nominations submits the following list of officers and committeemen:

Officers

President	M. C. James, District of Columbia
First Vice-President	A. S. Hazzard, Michigan
Second Vice-President	A. H. Wiebe, Tennessee
Secretary-Treasurer	G. E. Sprecher, Wisconsin
Librarian	W. C. Beckman, Colorado

Committee on International Relations

Stillman Wright, District of Columbia, *Chairman*
A. G. Huntsman, Ontario
A. L. Pritchard, Ontario
R. E. Johnson, Minnesota
R. W. Eschmeyer, Tennessee
M. J. Lindner, Mexico, D. F.
Fred A. Thompson, New Mexico

Committee on National-State Relations

O. L. Meehean, District of Columbia, *Chairman*
A. F. C. Greene, Wyoming
Minor E. Clarke, Kentucky
Willis King, Tennessee
W. F. Carbine, District of Columbia

Committee on Hydrobiology and Fish Culture

G. E. Butler, Manitoba, *Chairman*
Dwight A. Webster, New York
John B. Moyle, Minnesota

S. F. Snieszko, West Virginia
G. C. Armstrong, Ontario
D. S. Shetter, Michigan
Albert M. Powell, Maryland

COMMITTEE ON COMMERCIAL FISHERIES

Andrew W. Anderson, District of Columbia, *Chairman*
John L. Hart, British Columbia
Carl F. Kolbe, Ontario
Howard A. Schuck, Massachusetts
W. A. Kennedy, Manitoba
R. V. Truitt, Maryland
G. N. Washburn, Missouri

COMMITTEE ON NAMES OF FISHES

Reeve M. Bailey, Michigan, *Chairman*
J. R. Dymond, Ontario
Ralph Hile, Michigan
George S. Myers, California
W. A. Clemens, British Columbia
E. C. Raney, New York
C. M. Breder, New York

CONCLUDING BUSINESS

THE RETIRING PRESIDENT: Before the new President comes to the rostrum, I should like to make a few comments. First, I want to thank you for your co-operation during the past year.

It has been an honor to serve you. I particularly want to thank you for your co-operation in connection with this meeting. The sessions have been exceptionally well attended, and the co-operation in completing the program on schedule has been all that anybody could ask for.

I bespeak for the incoming officers and committees the same co-operation during the coming year. If that is forthcoming, I am sure your Society next year will be in a much stronger position all the way through.

The incoming President and I are of entirely different schools. My school is the school of hard knocks. He has several sheepskins to show for his collegiate work. More than that, he has served in a national capacity, whereas I have had to serve only in a state capacity.

I feel highly honored in turning over the gavel, and at this time I wish to ask Capt. C. F. Culler of the United States of America and Doctor A. L. Pritchard of the Dominion of Canada to escort the new President to the Chair. [Applause.]

THE PRESIDENT-ELECT: Thank you, gentlemen. Mr. Gordon, members of the Society and your very efficient bodyguard, I thank you very much. In the long and honorable history of the Society the induction of a new President is not an event of momentous importance. The brilliant and illustrious individuals who have occupied the Chair in the past have set a record such that the Society can take a new President in its stride, without too much internal agitation.

However, for the individual whom you have honored by election to the Presidency, the situation is very different. It is not a matter of minor importance; to him it is a matter of great importance to have the privilege of serving you. The importance of the position is such that he has, first, a feeling of deep personal gratification that so much confidence has been placed in him.

Second, he is deeply impressed with the responsibility of conducting the affairs of the Society, because again the record of the past has been so illustrious. I very distinctly have that feeling and thank you deeply for your confidence.

My feeling of responsibility is somewhat emphasized by reason of the splendid achievements of my predecessors. We all know that a year ago, when Seth Gordon took office, there was a feeling that the affairs of the Society were in a somewhat precarious state. The Society was almost a war casualty.

Now there is no doubt for the future. The condition of the Society in terms of membership and finances has undergone great improvement. I happen to know that it was the very strenuous efforts of Seth Gordon, of George Sprecher, and of all the other officers that brought this about. It was not simply happenstance. With that immediate background, I am much impressed with the responsibility of doing my best at least to maintain that position.

I recognize that incoming Presidents are expected to put in a very brief appearance, spread their wings momentarily, and then possibly, like a queen bee, retire to the hive and engage in prolific and fecund activities until a year hence, when they emerge briefly into the sunlight, have their brief day, and then go down in history and legend. I intend to honor that tradition, but there are one or two minor items of business which I find it necessary to bring up.

To proceed to the first anti-climax of my administration, I have to refer to the fact that we are faced with the necessity of a change in the editorial board, which, according to the new constitution replaces the editorial committee. You will recall that Dr. Hile, in his report yesterday, remarked that he had in mind the possibility of relinquishing his position. In order to be sure that I had not misunderstood him, I conferred with him, and found that it would take a major revolution leading to a dictatorship to induce Ralph Hile to continue.

We are, therefore, faced with a new appointment to the chairmanship of the editorial committee. In any case, under the rule it is the chairman of the committee who is responsible for the handling of the TRANSACTIONS. I believe he has the official title of "editor."

With no surprise to any of you, I may say we have been able, very fortunately, to induce Dr. Lloyd L. Smith of Minneapolis to accept this position, and Dr. Smith will take over as chairman of the editorial committee. Also, the associate editors must be appointed. Under the by-laws, the committee shall consist of eight members. I therefore wish to announce the following individuals as members of this committee:

Brian Curtis
Dr. Bertil G. Anderson
Dr. George A. Rounsefell
Dr. D. S. Rawson
Kiyoshi G. Fukano
J. W. Leonard
Reeve M. Bailey

DR. BECKMAN: I move that Dr. Ralph Hile be given a rising vote of thanks for his efforts as editor in getting out the last four volumes of the TRANSACTIONS. [Carried unanimously.]

At 5:30 p.m., September 16, 1949, the Seventy-ninth Annual Meeting of the American Fisheries Society was adjourned.

Appendices

INSTRUCTIONS FOR PREPARING MANUSCRIPTS FOR THE TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY

(Revised 1950)

Please check each item below before the final typing of your manuscript and help your Society reduce the costs of publication, save your Editorial Board (which works gratis) much needless work, time, and expense, and avoid delay in the publication of the *Transactions.*

The following instructions were not drawn up arbitrarily but were condensed from the regulations contained in the best style manuals (Government Printing Office Style Manual; University of Chicago Style Manual). Certain instructions may appear unnecessary, but they are nevertheless essential for the proper handling of materials by the printer and the editor.

I. MECHANICAL DETAILS

1. Manuscript must be typewritten double-spaced, including titles, headings, legends for tables and illustrations, and literature citations. Use one side only of sheet. Do not fold manuscript. Write manuscript only in simple upper and lower case. Do not use all capital letters for any purpose and underscore only where italics are intended. No manuscript will be accepted unless it conforms to this style.

2. Carbon copies will not be accepted. Do not use thin, transparent paper. Heavy bond paper is preferred.

3. Margins at top, bottom, and both sides must be no less than 1¼ inches to allow space for the insertion of directions to the printer and necessary corrections.

4. Pages must be numbered in consecutive order, including the literature cited, tables, charts, and photographs. Tables and legends of charts and illustrations must be inserted near their place of reference in the text.

5. Illustrations. Make separate pages of tables with headings (not of leader work), of legends of diagrams, charts, and illustrations, and limit the number to those absolutely necessary to clarify or supplement text. *Tables and cuts cost money!* Only sharp, glossy photos can be used. All drawings, charts, and diagrams should be prepared in waterproof India ink on Bristol Board, other perfectly smooth white paper or cardboard, or tracing cloth. Graph paper must not be used. No erasures should be made. Shading should be limited to a minimum and when used the shading lines should be kept open. The curves of graphs should be drawn much bolder than any guide lines or ruling. Lettering should be bold and sufficiently large and spaced apart so that the letters or numbers will not be less than 1 millimeter high or come in contact when reduced. Drawings should be made at least twice the size required for reproduction, and when large should be of proper proportion so that they will not exceed 4¼ by 6½ inches (inclusive of legends) when reduced. All explanatory matter other than the units along each axis of a graph or diagram and those designations needed for clarity should be placed in the legend. The legend, which should be typewritten on a separate sheet, will be set in type below the figure.

Make proper reference in text to all plates, maps, charts, and tables, and with Arabic, not Roman, numerals.

6. Footnotes in text should be numbered consecutively and should be placed immediately after the full line of text in which the reference mark occurs, but do not break a line of text to insert footnote. Separate the footnote from the text by

two horizontal lines, one above and one below the note. In each new table footnotes should begin with 1.

7. THE TITLE of the manuscript, together with the author's name (write out in full either one or both of the Christian names and do not use "by"), position or department, and post office address, should always appear at the top of the first page of the manuscript as follows, allowing at least *triple space between lines* to permit the insertion of instructions to the printer.

REPORT ON THE DISEASES OF BROOK TROUT

JOHN EDWARD DOE
Department of Conservation, Lansing, Michigan

8. UNDERSCORE (italics) all scientific names of genera and species, both animals and plants, in both text and tables. Do not underscore or use all capital letters for scientific names of a category higher than the genus: Esocidae; *Esox lucius. Do not underscore any words unless italics are intended.*

9. Inspect papers in the last volume of the *Transactions* if you have questions concerning the arrangement of materials.

II. STYLE

10. BIBLIOGRAPHIC REFERENCES in text should give name of author and year of publication in parentheses, thus (Doe, 1932). Do not use letters or numbers or footnotes for references. If more than one publication by the same author is given for a year, use the alphabet to designate the correct paper, thus (Doe, 1932a) or (Doe, 1932b). In the bibliography do not repeat the author's name if reference is made to more than one of his publications, but list his publications in chronological order beginning with the earliest one. In citing a joint publication invert the name of the senior author but not of the co-author or co-authors. *Do not include any reference not mentioned in the text.* List authors in alphabetical sequence. Capitalize the first word and proper names only in the title. Follow the arrangement given below to be placed at end of paper:

LITERATURE CITED

DOE, JOHN C., J. W. BROWN, and H. W. GREEN
1939. Report on the diseases of brook trout. Trans. Am. Fish. Soc., Vol. 68 (1938), pp. 450-461.

Note that the year of publication precedes the title and the year of the meeting is stated in the reference.

Please check your references carefully as to titles, spelling, capitalization, italics, diacritical marks, abbreviations, etc., against their original sources, after the final typing, and *state beneath your bibliography that you have done so.* Many bibliographic titles published in the *Transactions* have been found to be incomplete and very inaccurate. Help us correct this situation.

11. TABLES. Every table should have a heading and must be typewritten on a separate page. Insert tables among the text pages near the points where they are

Item	Number of fish	Percentage of total	Average length millimeters	Months	Cost of diet per pound
Brook trout surviving experiment No. 2	23	5.8	6.5	April-September	$0.25

discussed. In preparing tables please be certain that they are not too large to appear on a single printed page. Number tables consecutively with Arabic, not Roman, numerals (1, 2, 3, etc.). Abbreviate the word "number" (No.) when referring to a special number—not when referring to quantity or things. Spell all other words in tables, including such words as "millimeters," "ounces," and "average" (except months *with date,* in body of table), and capitalize, as a rule, the first word only in headings in the 1st column or over other columns. Precede all decimal numbers with zero. Use dollar sign only with first number at top of column and under each cross rule.

12. Capitals. Capitalize words when used as part of a proper name or of an identifying number or letter, or when referring to a particular State, Government, and to organized bodies, or when used as proper names. For example: Lake Michigan, State of Michigan, or the State, the Province, the Republic, or the National and State Governments, Washtenaw County, Ann Arbor Township, Huron River, Pacific Ocean, North Atlantic, Northern States, Reservoir No. 1, Hoover Dam, Pond No. 1 or Pond A, State Fish Farm No. 1, Pisgah National Forest, American Fisheries Society.

Capitalize names of sections of the United States, or of any other country, as Middle West, but use lower case for a term prefixed to any such sections, as eastern North Atlantic States.

Capitalize any term (except page or pages and age group) preceding Roman numerals, as Article I, Chapter II, Sample VI, etc. Also capitalize such terms as Appendix 1 or Appendix A, Experiment 2, Table 4, and Figure 8 (referring to illustrations).

Use lower case for scientific and common names of species. Capitalize scientific names of higher categories.

13. Abbreviations.

(a) Abbreviate the following:

Clock time, if connected with figures—2:30 a.m.
Temperatures, F. (Fahrenheit).
Degrees, whether referring to temperatures, longitude and latitude, or angles, etc.—75°, 75° F., 75° C.
Number, if preceding figures—No. 125; otherwise spell out.
United States, if preceding name of a department or a bureau of a vessel, etc.—U. S. Department of the Interior, U. S. S. *Indiana.*
Months, in body of tables and footnotes to same when followed by day of month—Apr. 5-Sept. 2 (but April-September).

(b) Do not abbreviate the following:

States, cities, etc.
Months, in text or in headings of tables—April 5-September 2.
Measures and weight, except p.p.m., 6 inches, 20 millimeters, 5 ounces, 1.5 acres, etc.
Percentage, 12 percent, a percentage of 25.5.

14. Numerals. Spell out all *isolated* numbers less than 10, but use figures in a group of enumerations when any one number of that group is 10 or greater. Do not spell out numbers of two or more digits (except round numbers of approximations: estimated at five hundred; a thousand fish), and always use a comma in a number of four or more digits. Treat alike all numbers in a series of connected groups. For example: There were nine trout. There were 9 trout, 120 bass, and 50 pike.

Use figures for all enumerations of quantities and measurements, such as dimension, weight, area, volume, distance, clock time, time, money, percentage, degrees, proportion or ratios, ages, dates, page numbers, decimals, and mixed numbers (spell out common fractions if alone: one-eighth inch). For example: $3.00 per 20 pounds; 5 feet 6 inches; 10 miles; 6 acres; 15 cubic centimeters; 4:30 p.m.; fish died in 1 hour and 20 minutes; 25.5 percent; 75° F.; 1:10,000; trout 2 years 6 months old; 2-year-old trout; June 29, 1936; the 1st of January, 1938; the 20th day of March; 1937-38; 4.5 p.p.m.; 0.25; 1½ pages; page 215.

Write 8 by 12, not 8 x 12 unless multiplication is indicated. Write 50-50, not "fifty-fifty."

Do not use two figures when two numbers appear together, unless the first enumeration exceeds 100: ten 12-room houses; twenty 6-inch trout; 120 6-inch trout.

Spell out figures beginning a sentence, but avoid such use of numerals if possible. Spell out both numbers of two related amounts at the beginning of a sentence in such expressions as "Twenty to twenty-five trout," but write "Two hundred fifty bass and 325 trout were shipped."

Spell out such indefinite expressions as the following: Between two and three hundred fish; there were thirty or forty thousand trout.

In expressing large numbers the word *million* (or a similar larger group term) may be spelled out: 20 million, 2¾ billions.

15. USE OF HYPHEN. Many compound words when used as nouns are not hyphenated but require the hyphen when used as adjectives. For example note the following sentence: "This species is adapted to *"cold water."* "Trout are *cold-water* fish." Write "fish culture," but "fish-culturist." Check your manuscript carefully for use of hyphen. The words, "subspecies," "upstream" and many other words originally of compound derivation are written without a hyphen.

Write "largemouth" and "smallmouth" as one word when referring to black bass.

III. SUBJECT MATTER

16. CONDENSE YOUR PAPER to the limit and omit all needless verbiage to reduce cost of printing. The manuscript should be simple, clear, concise, accurate, consistent, and complete. *Accuracy* in subject matter, in scientific names, and in bibliography is especially important. Have your associates read and criticize your paper before the final typing. PAPERS WHICH ARE TOO POORLY WRITTEN WILL BE REJECTED.

17. BE DEFINITE IN REFERENCES TO SPECIES. The scientific name, and wherever needed the *complete* common name, that will identify the species about which the paper is written should be included in the title as well as in the text, unless the number of species is too large. Such names as "bass," trout," and "pickerel" apply to any one of several species. Do not write "smallmouth," "brook," "rainbow," etc., when you mean "smallmouth black bass," "brook trout," "rainbow trout," etc.

18. THINGS TO AVOID. Words that do not appear in the dictionary in the sense employed should be avoided. The words "case," "instance," "show," "found," "gave," and "present" are greatly overworked in manuscripts.

Avoid the repeated use of *participles* which, as a rule, weaken sentences. In the following illustration note the improvement when the words in parentheses are used: "The principles underlying (that underlie) the production of beef are essentially the same as those involving (that are involved in) the production of bass."

Avoid *split infinitives.* Please check your manuscript for this exceedingly common error.

Avoid the use of *this* and *these* as substantives. Compare, for example, the following two sentences for effectiveness: *"This* was true in every *case." "The mortality* was *high* in every *pond."*

Avoid the use of a long series of nouns and adjectives as modifiers.

Avoid the use of such meaningless section headings as "Data" and "Discussion."

19. ABSTRACT OF PAPER. Give a brief abstract at the beginning of your paper. Do not include a "Summary" at the end of your paper; if "Conclusions" are given make them brief and not a duplication of materials in the abstract.

Prepared by the Editorial Board
February, 1937 (revised 1950)

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Compiled April 20, 1950

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